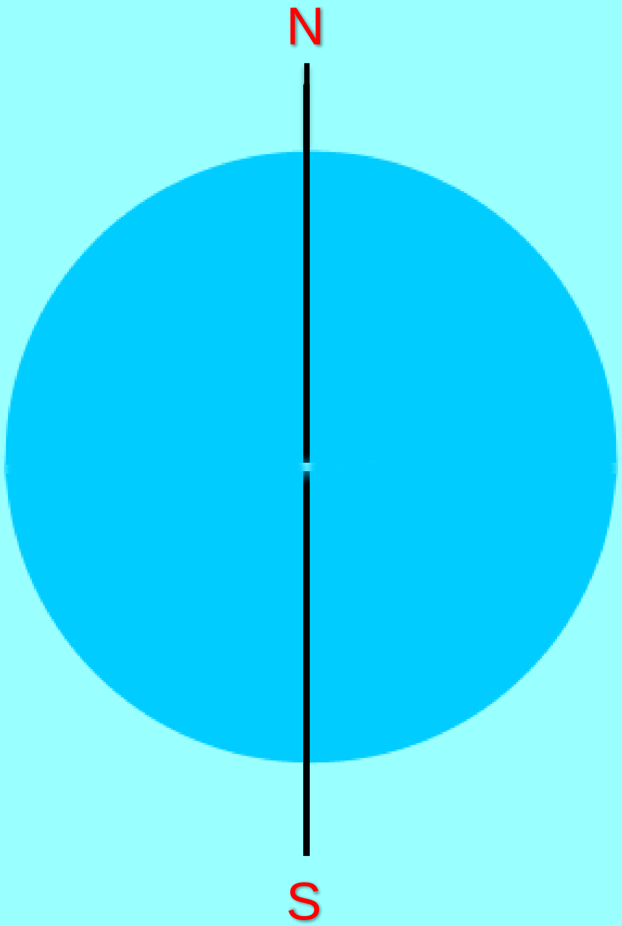
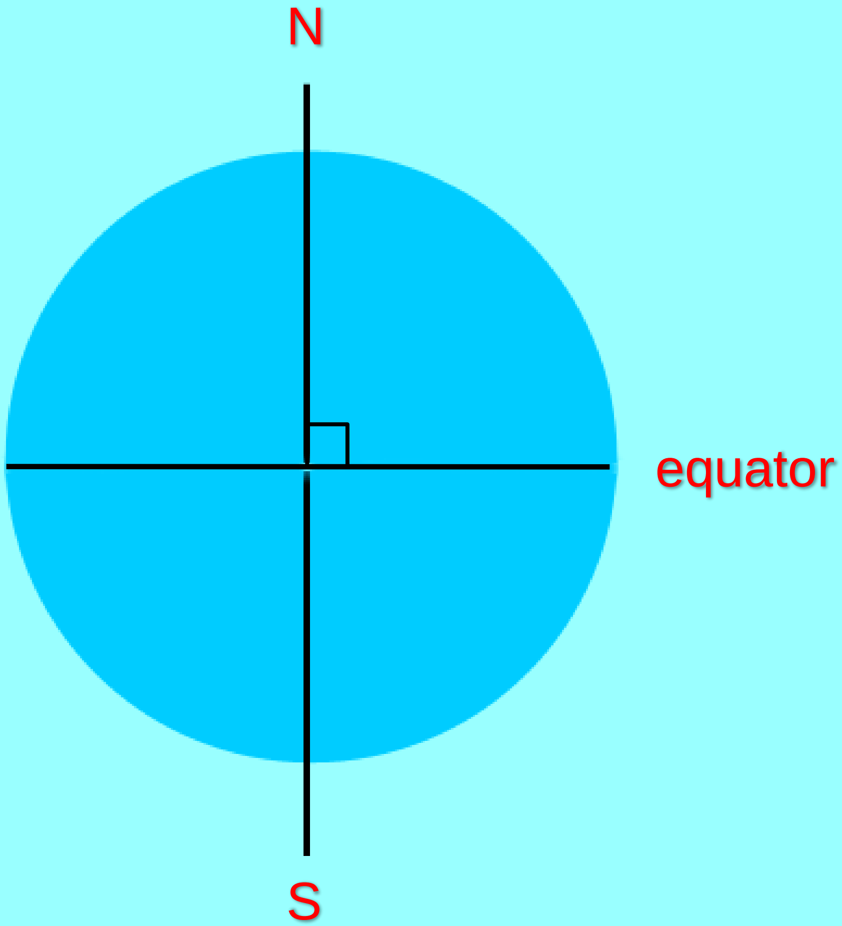
Let’s talk about motion

SIDE VIEW



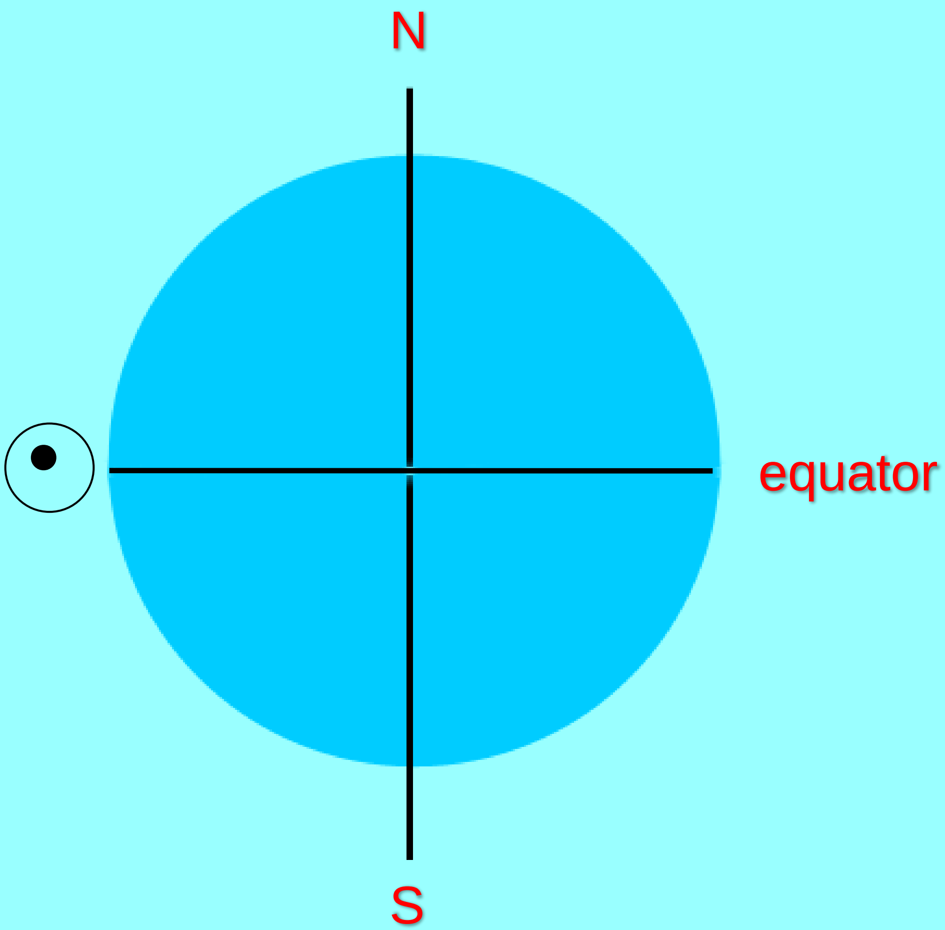
side-view of spinning Earth

SIDE VIEW



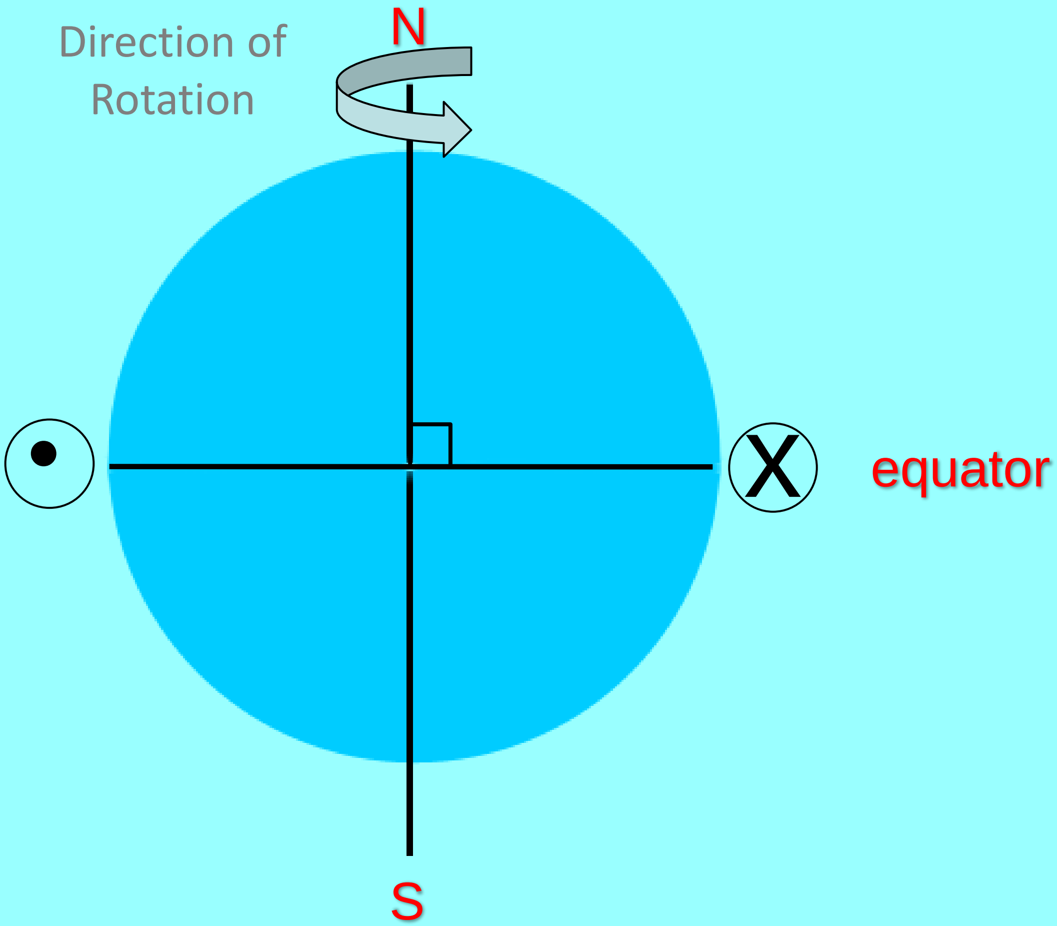
side-view of spinning Earth

SIDE VIEW



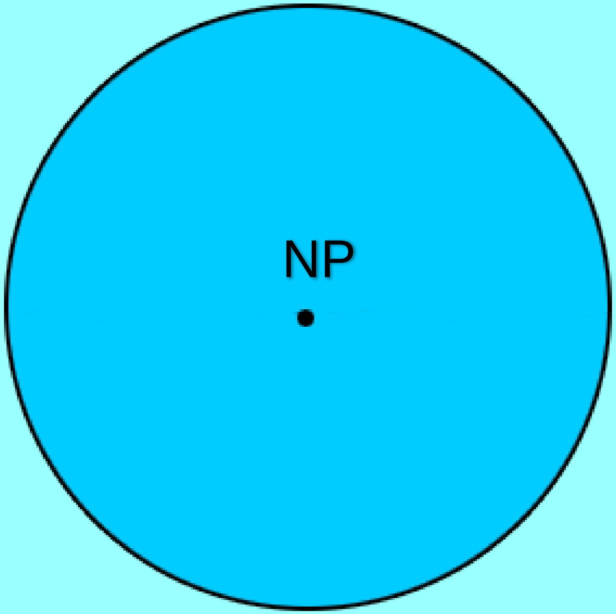
side-view of spinning Earth

SIDE VIEW



side-view of spinning Earth

TOP VIEW (above North Pole)

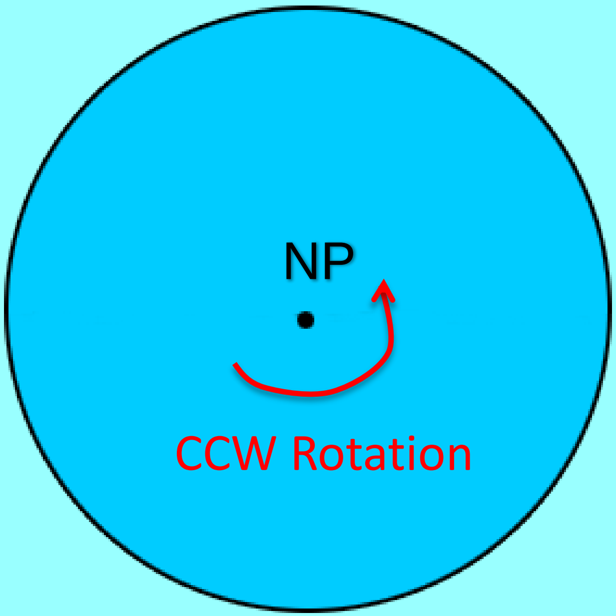


top view of spinning Earth

TOP VIEW (above North Pole)

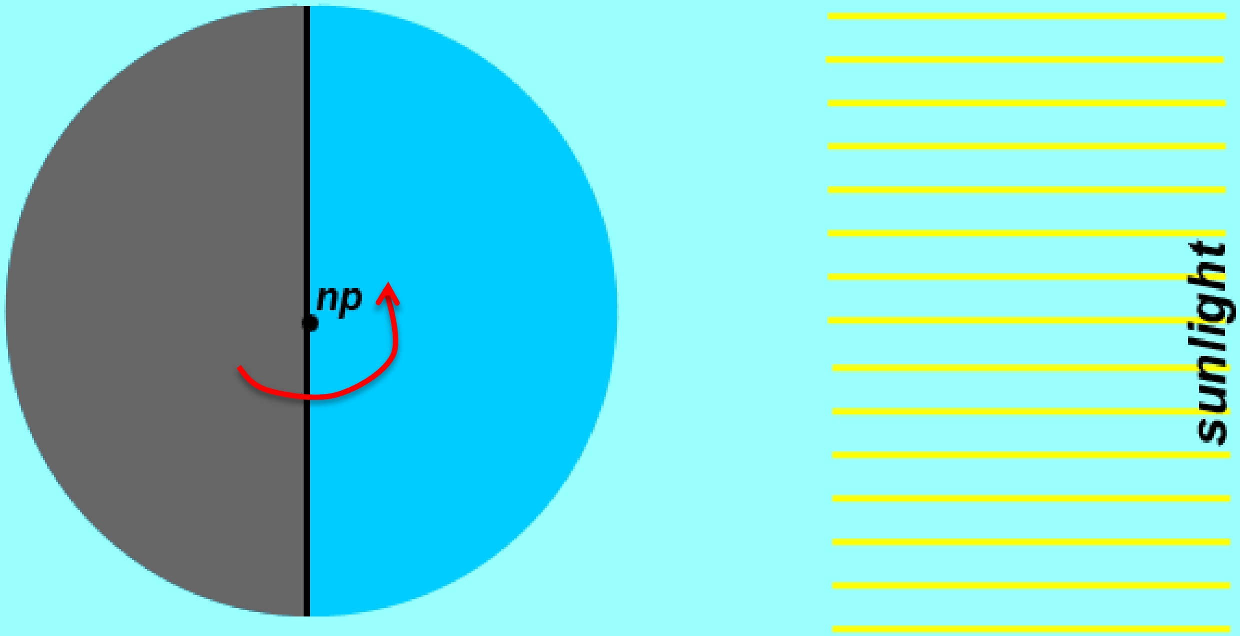
When viewed from above the North pole, the earth rotates in ***CCW*** direction

(when viewed from below the South pole, the direction is ***CW***)



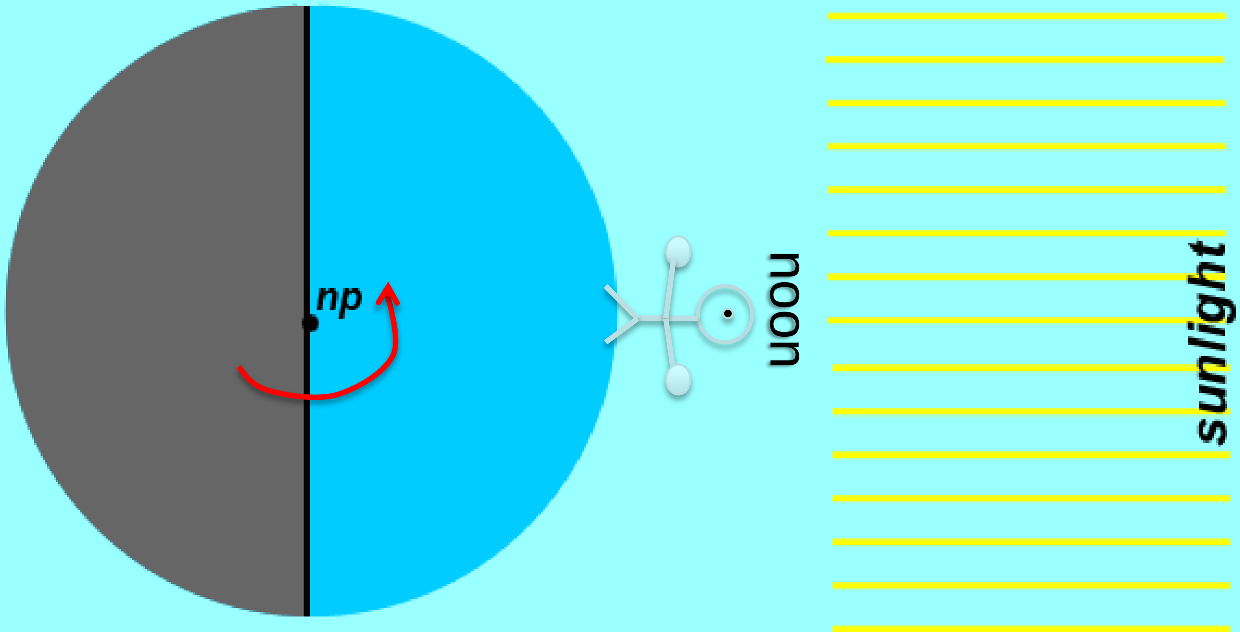
top view of spinning Earth

TOP VIEW (above North Pole)



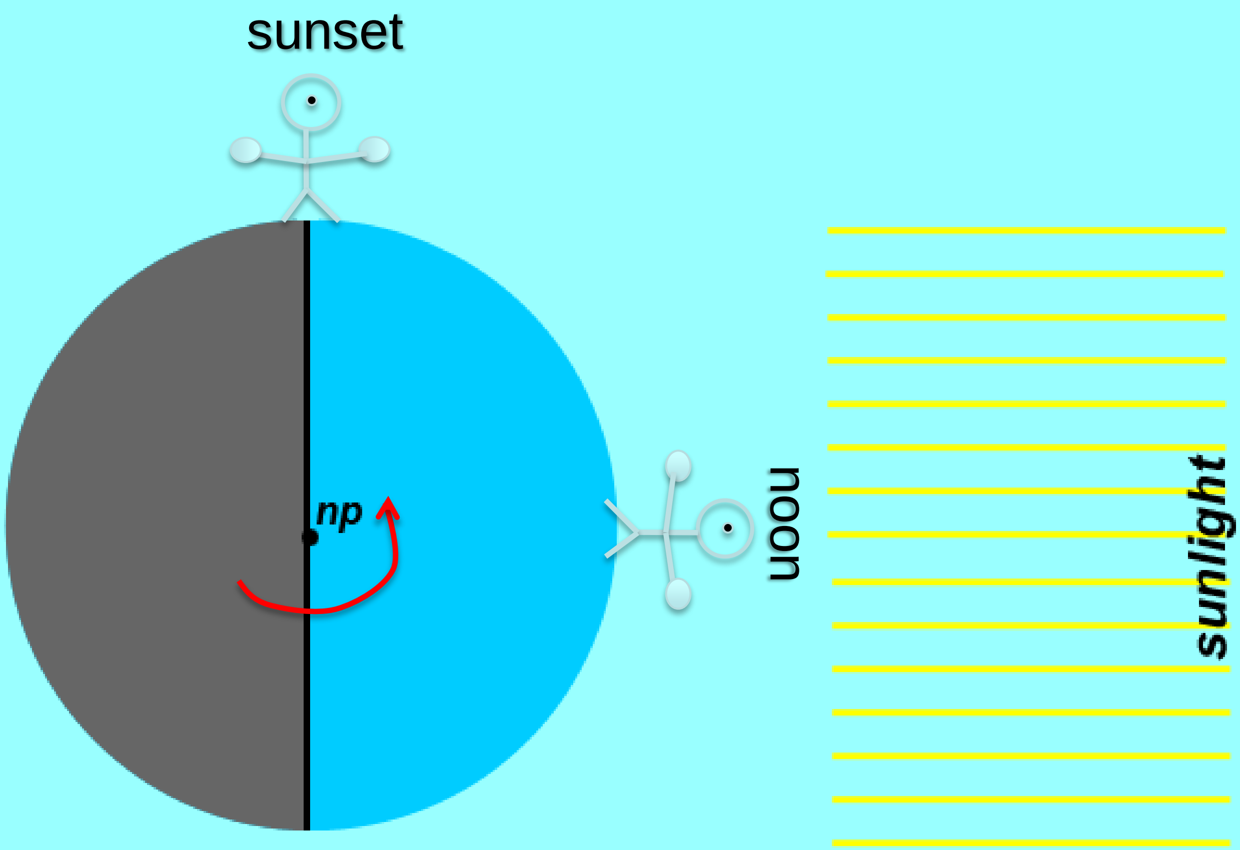
The Sun illuminates only half of any object at a time. This is why we have night.

TOP VIEW (above North Pole)



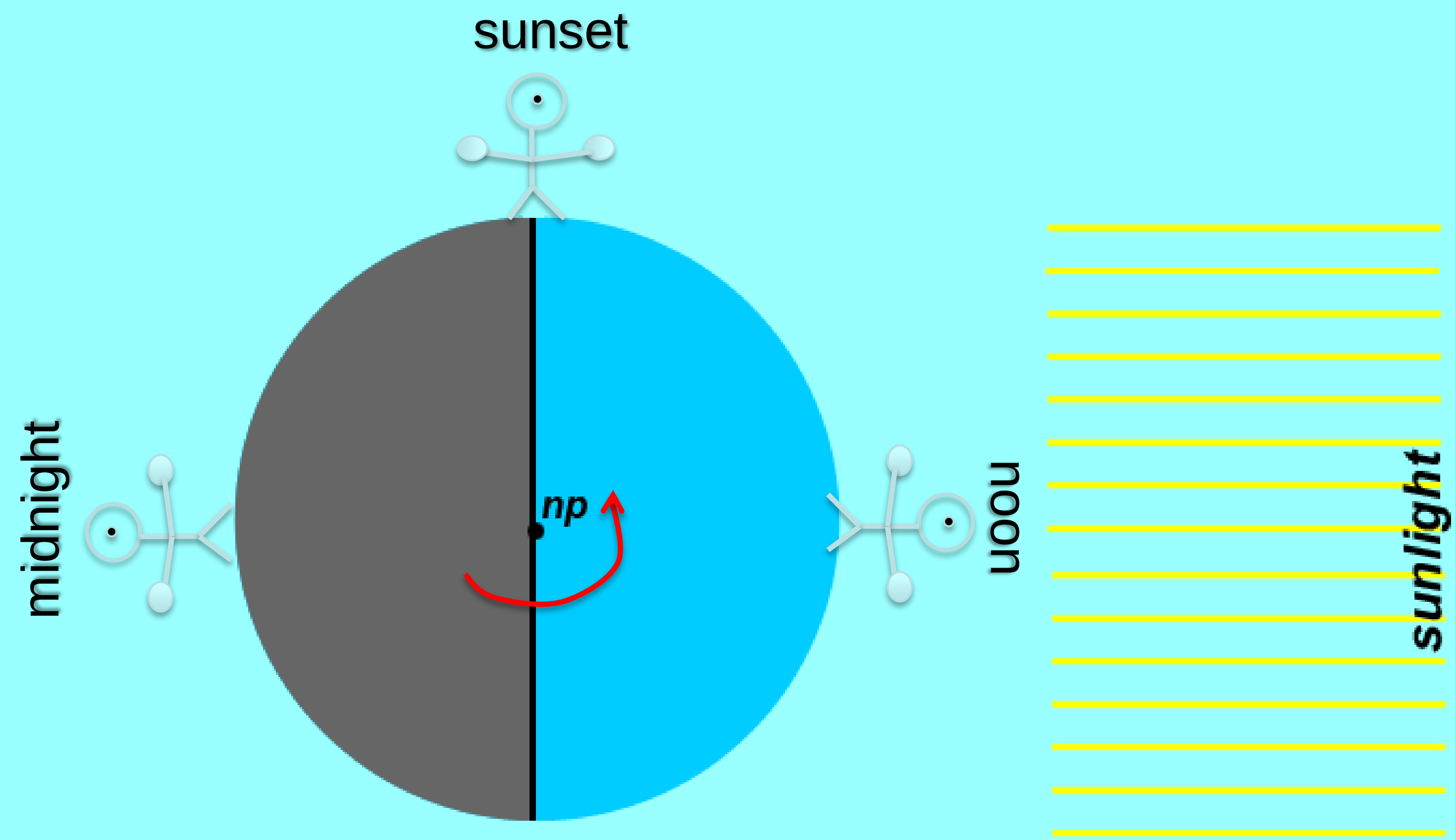
the time of day depends on your position on Earth relative to the Sun

TOP VIEW (above North Pole)



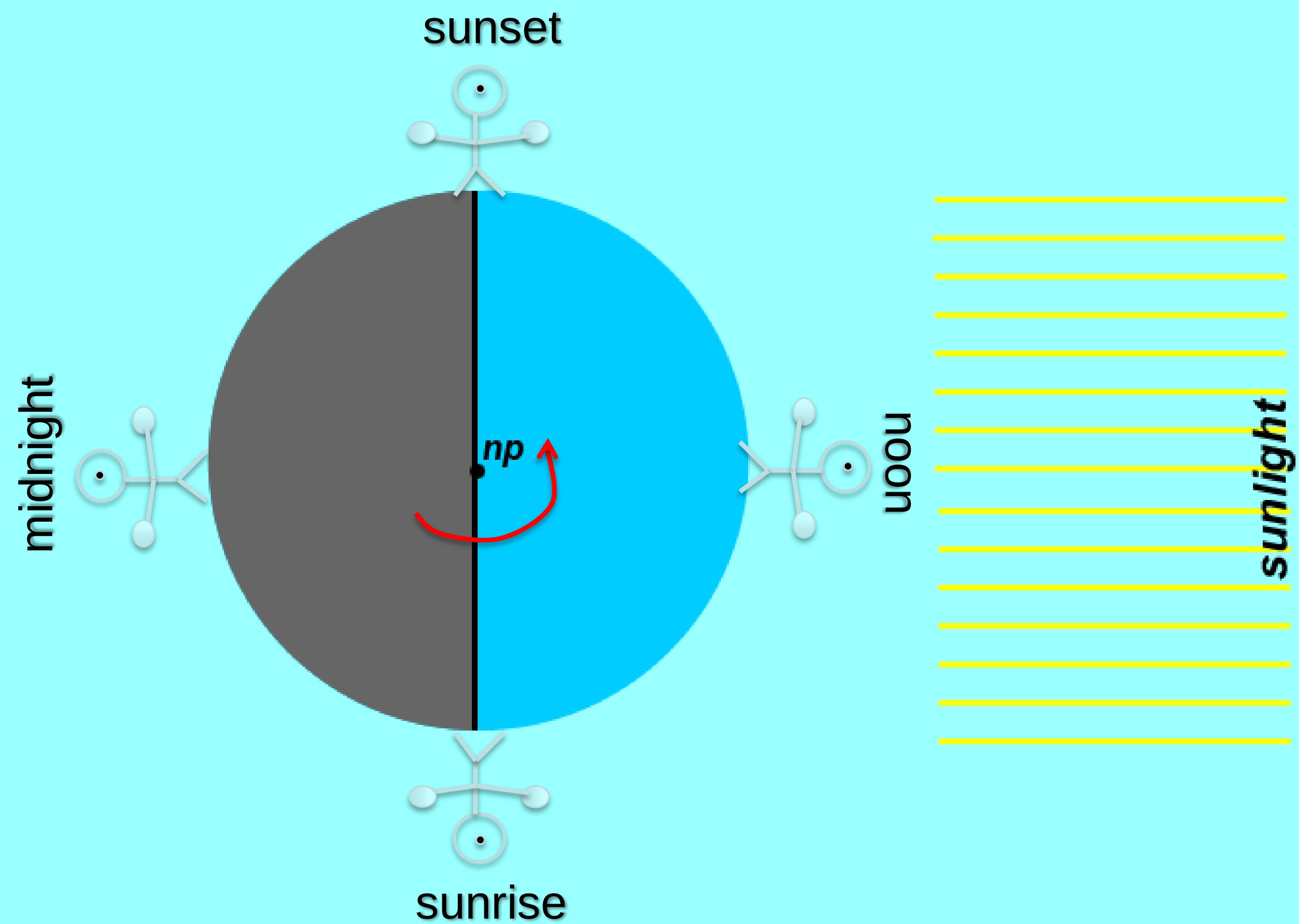
the time of day depends on your position on Earth relative to the Sun

TOP VIEW (above North Pole)



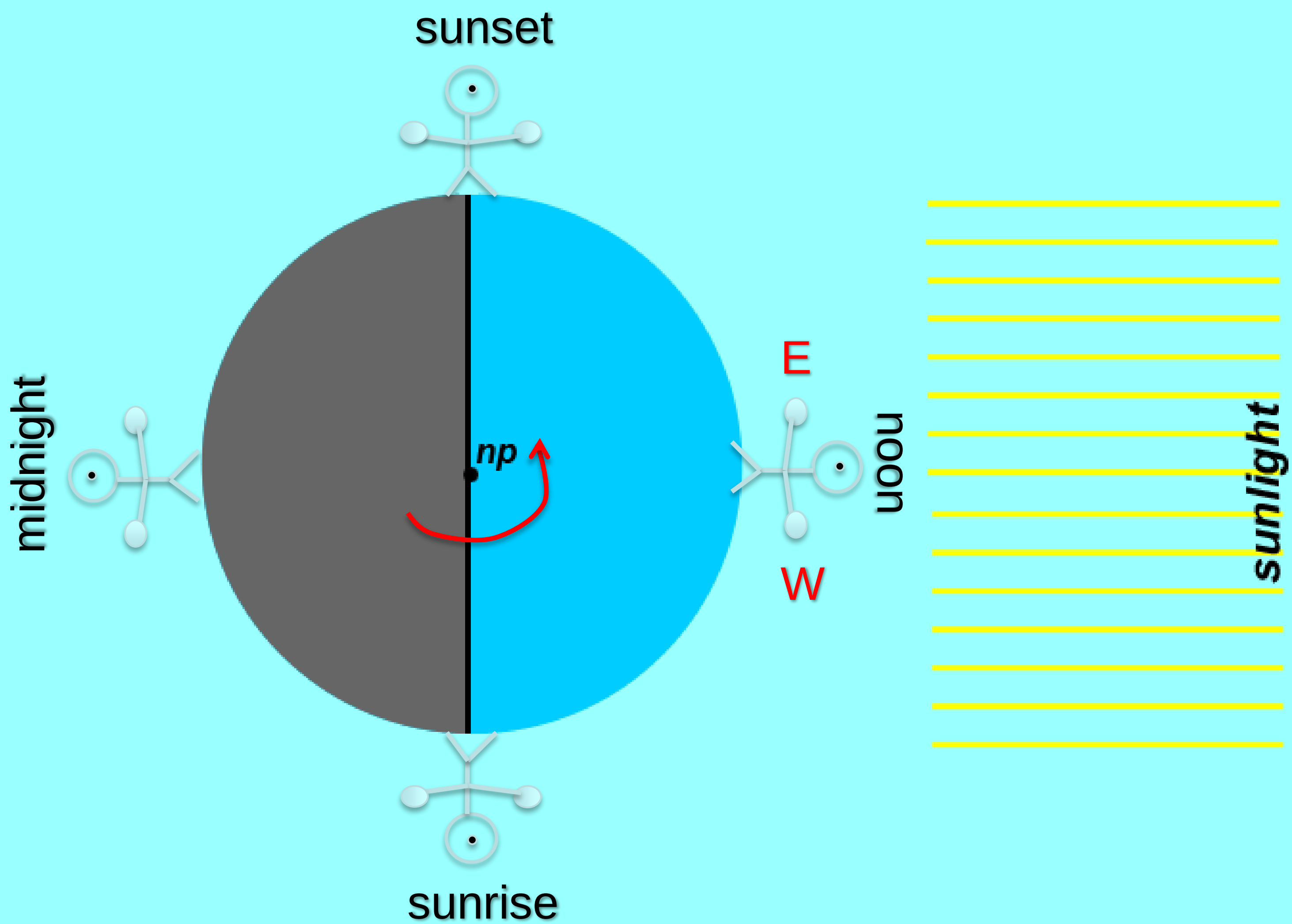
the time of day depends on your position on Earth relative to the Sun

TOP VIEW (above North Pole)



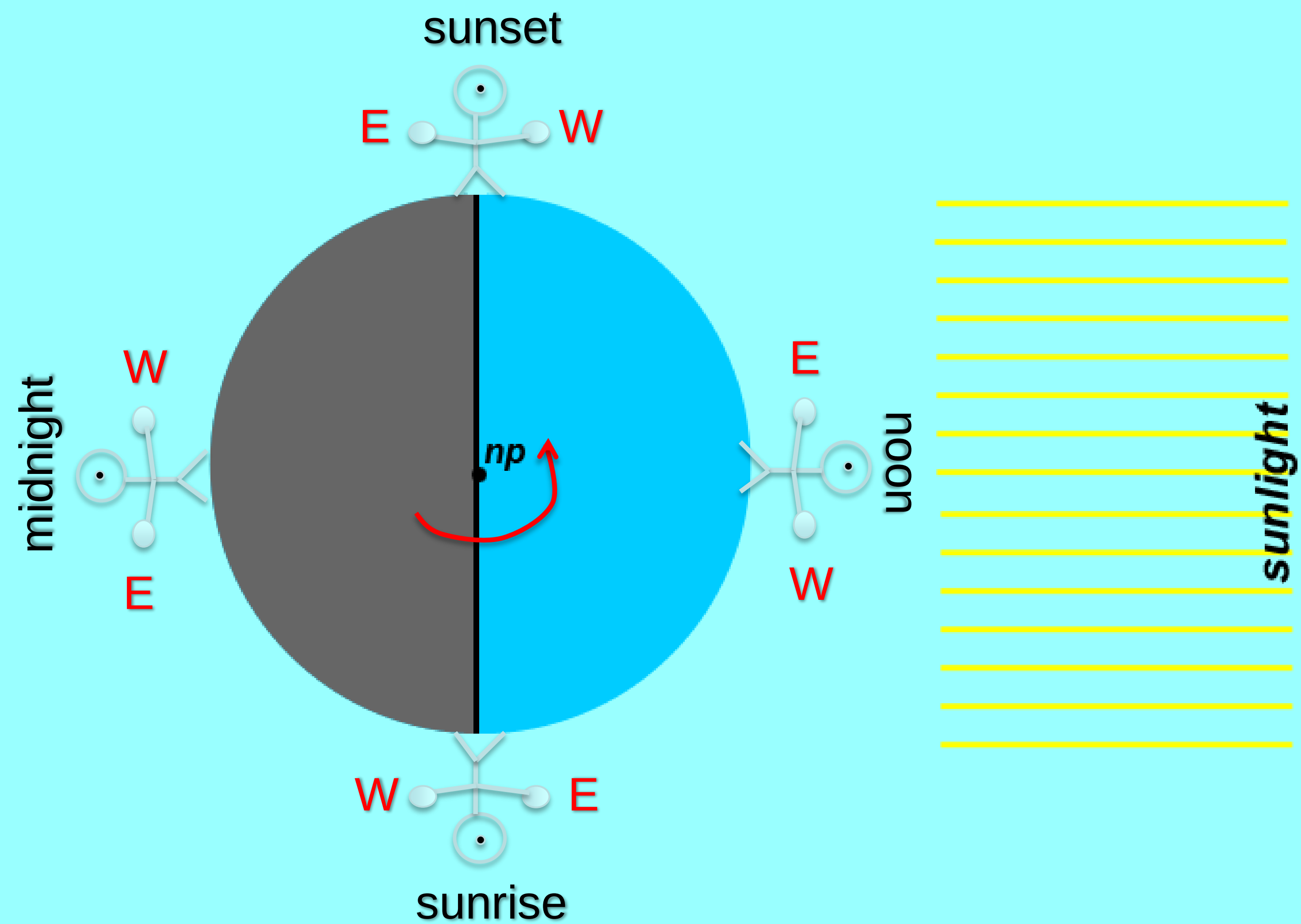
the time of day depends on your position on Earth relative to the Sun

TOP VIEW (above North Pole)



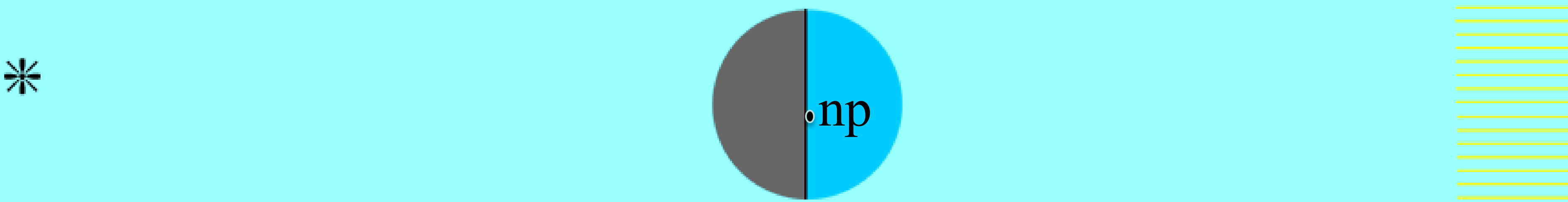
the directions E and W depend on whether you face NORTH or south

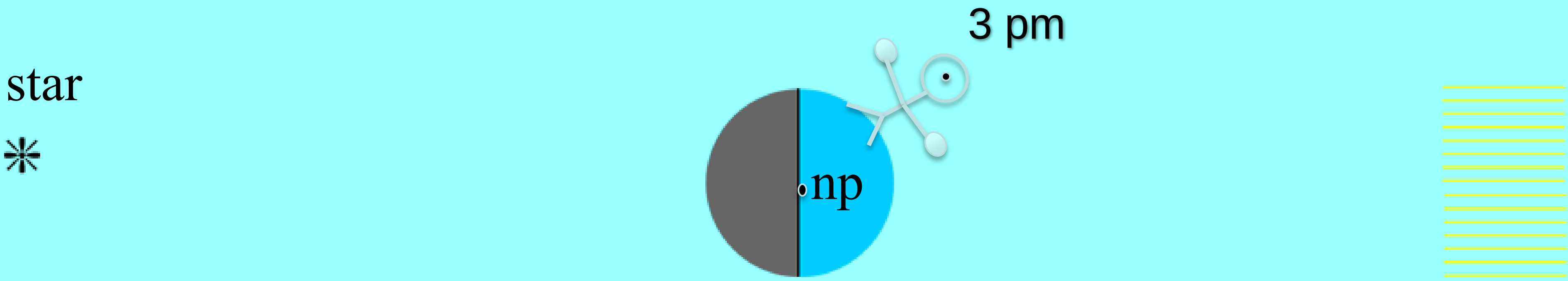
TOP VIEW (above North Pole)



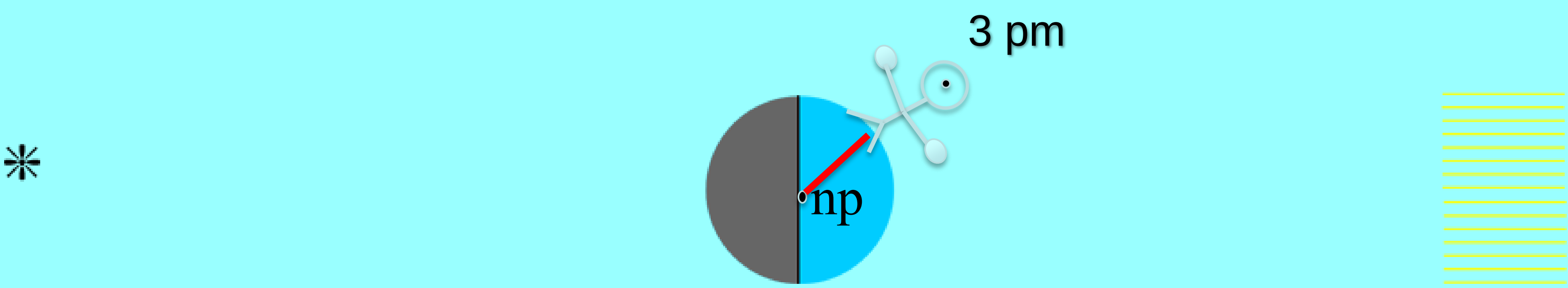
if you face NORTH your RIGHT hand is E, your LEFT hand is W
(and the opposite applies if you are facing SOUTH)

Your field of view of the sky: your HORIZON


np

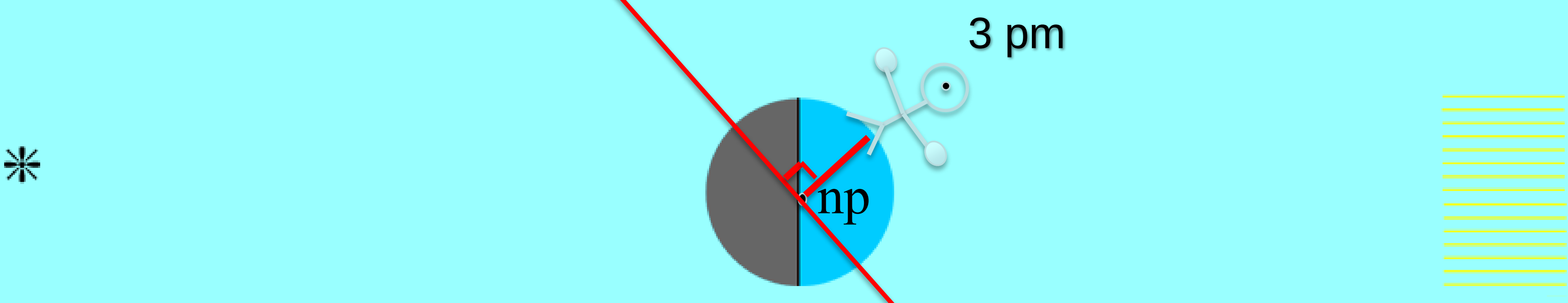


can I see the star on the left? Your horizon is defined by your time



We can't draw you on the Earth to scale, so there's a trick to find your horizon:

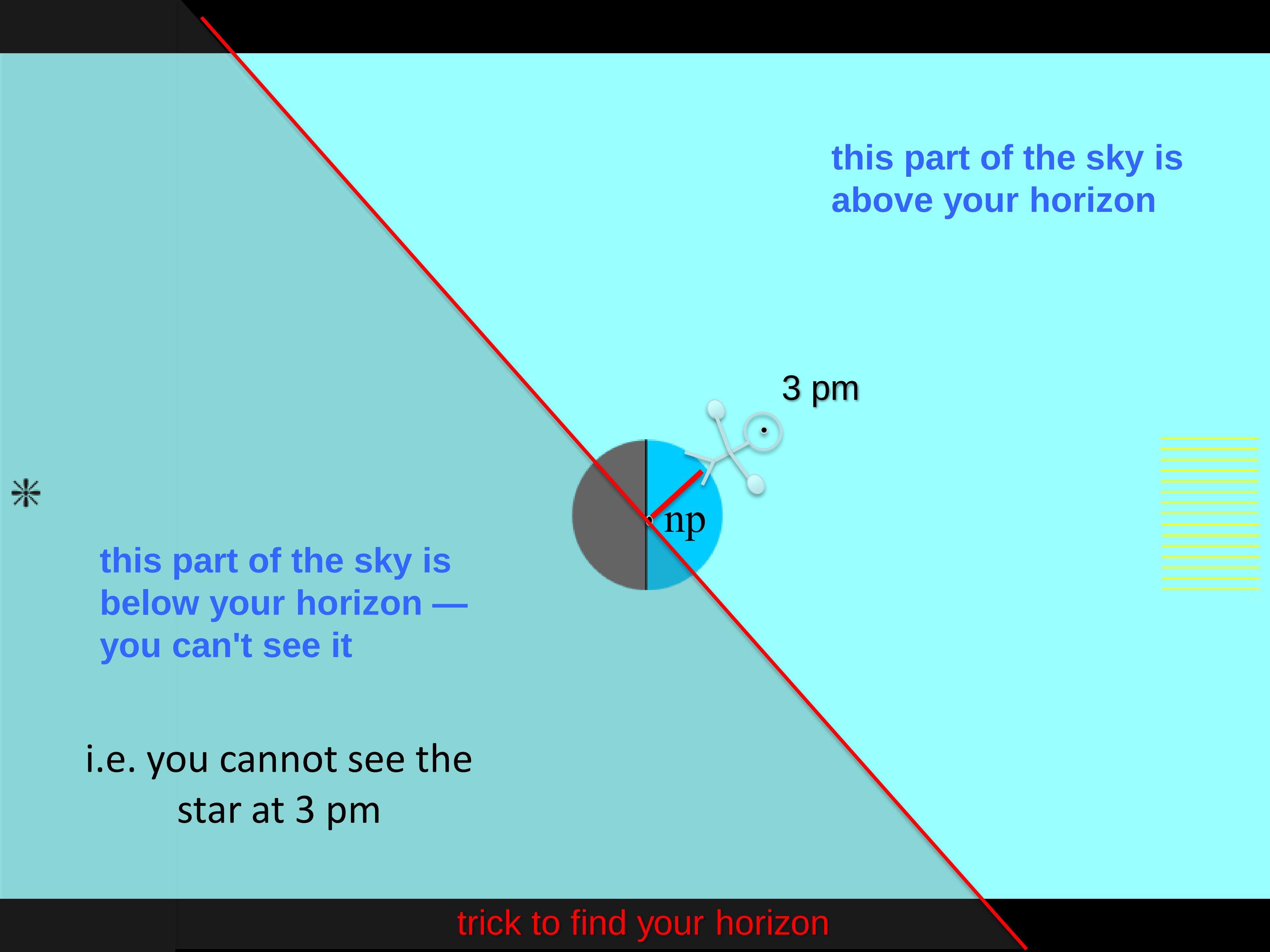
1. Draw a radius (i.e. line joining observer to center of earth)
2. Draw a line passing through the center that is perpendicular to radius

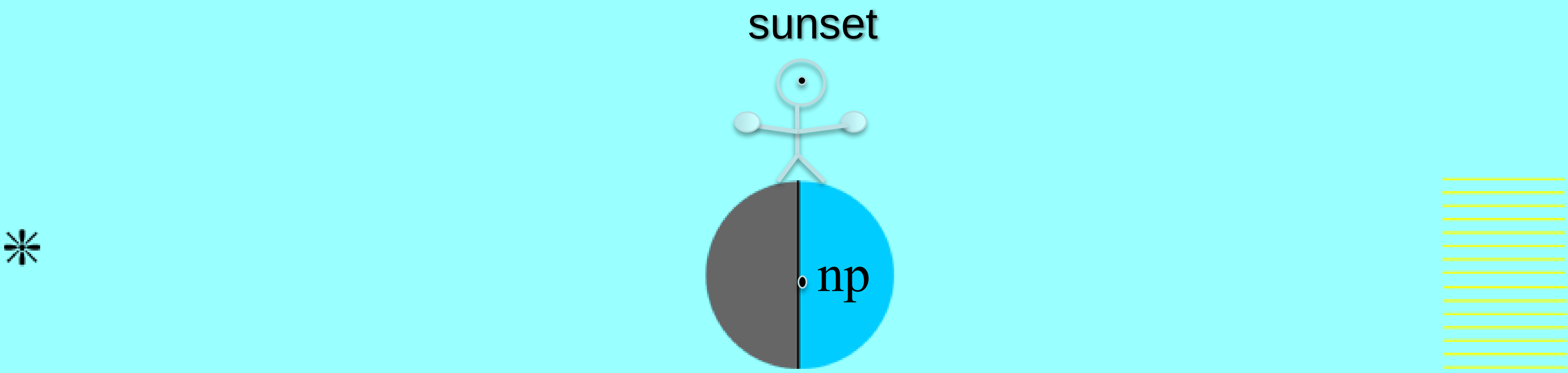


We can't draw you on the Earth to scale, so there's a trick to find your horizon:

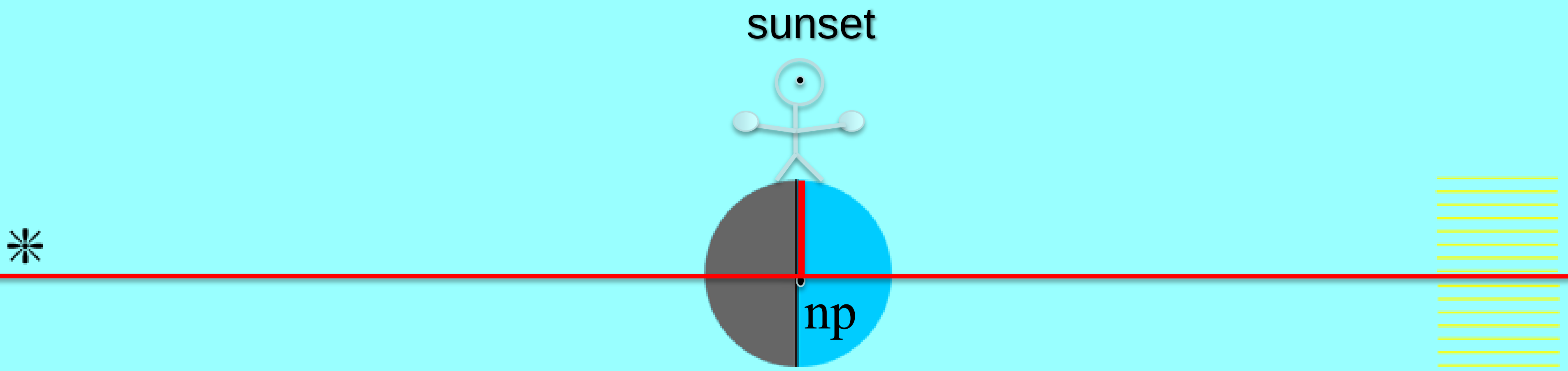
1. Draw a radius (i.e. line joining observer to center of earth)

2. Draw a line passing through the center that is perpendicular to radius

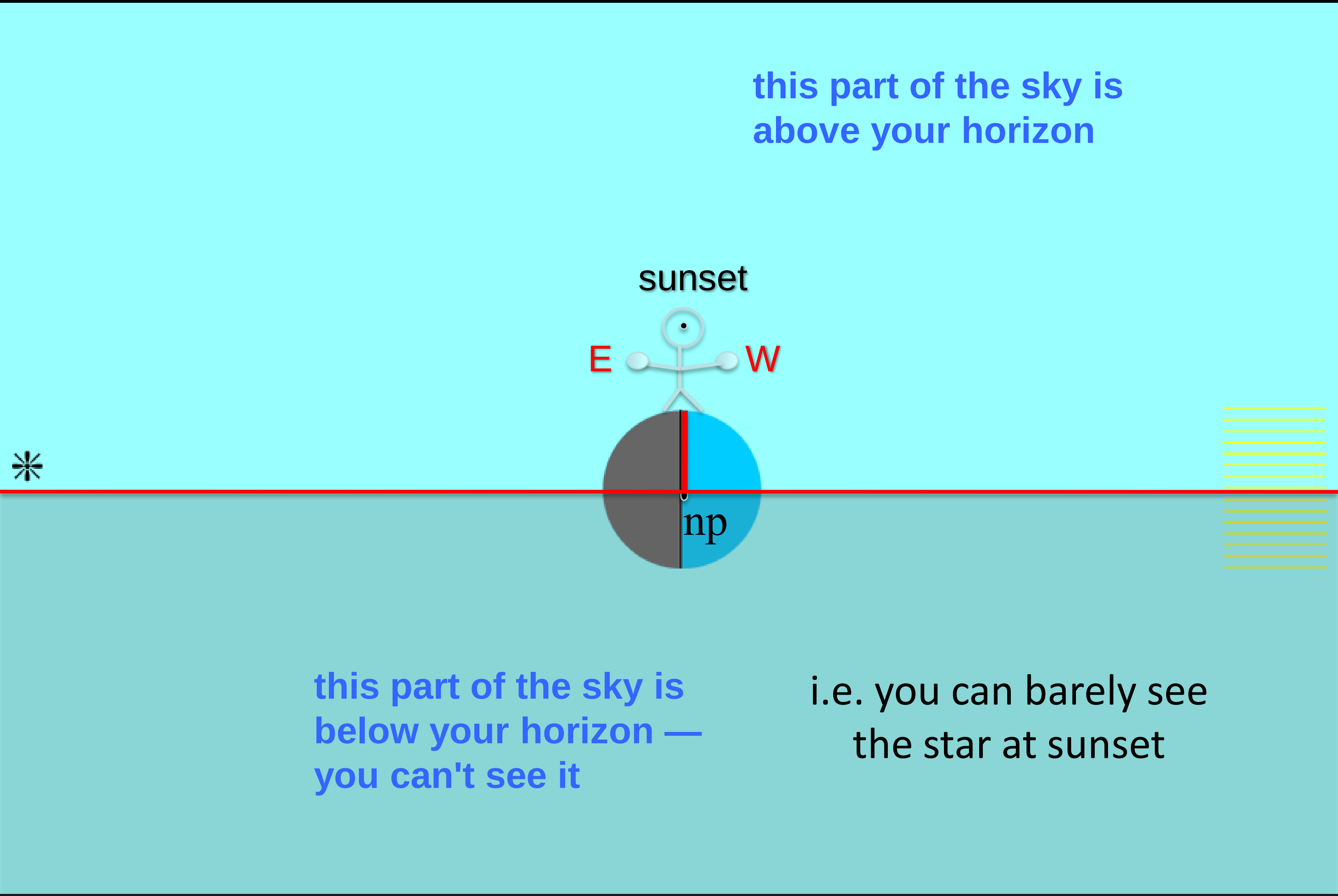

this part of the sky is
above your horizon
3 pm
np
this part of the sky is
below your horizon —
you can't see it
i.e. you cannot see the
star at 3 pm
trick to find your horizon



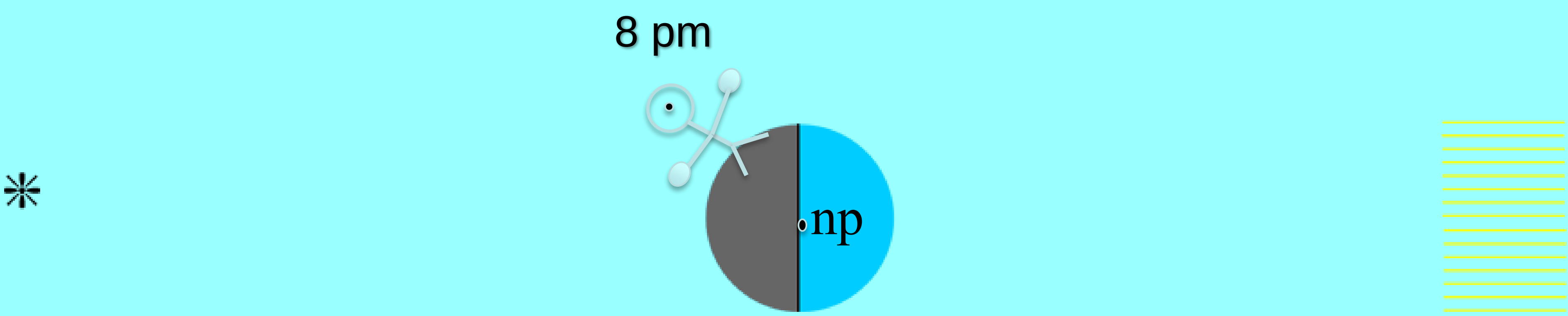
Can you see the star at sunset? Use trick from previous slide



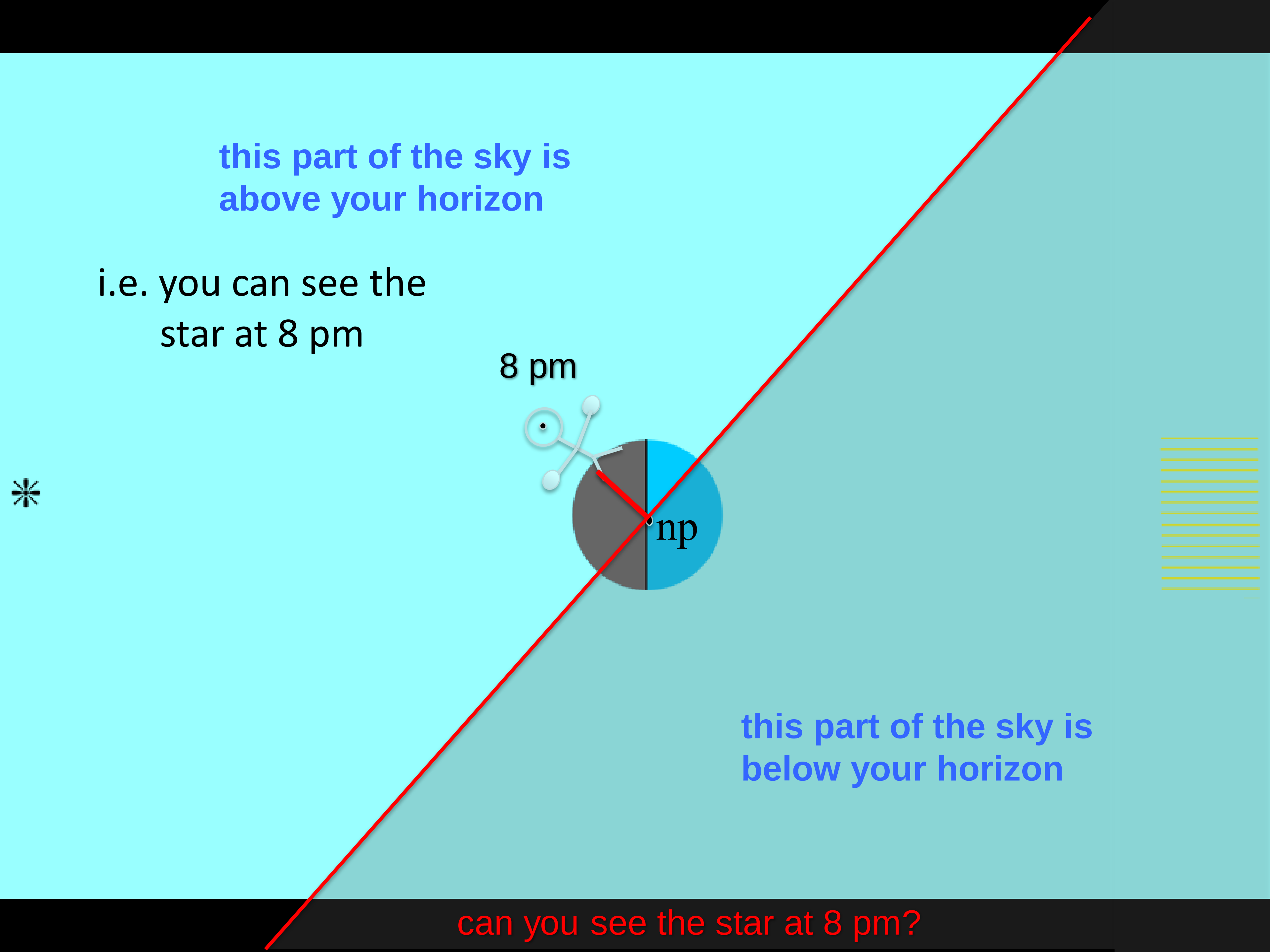
Can you see the star at sunset?

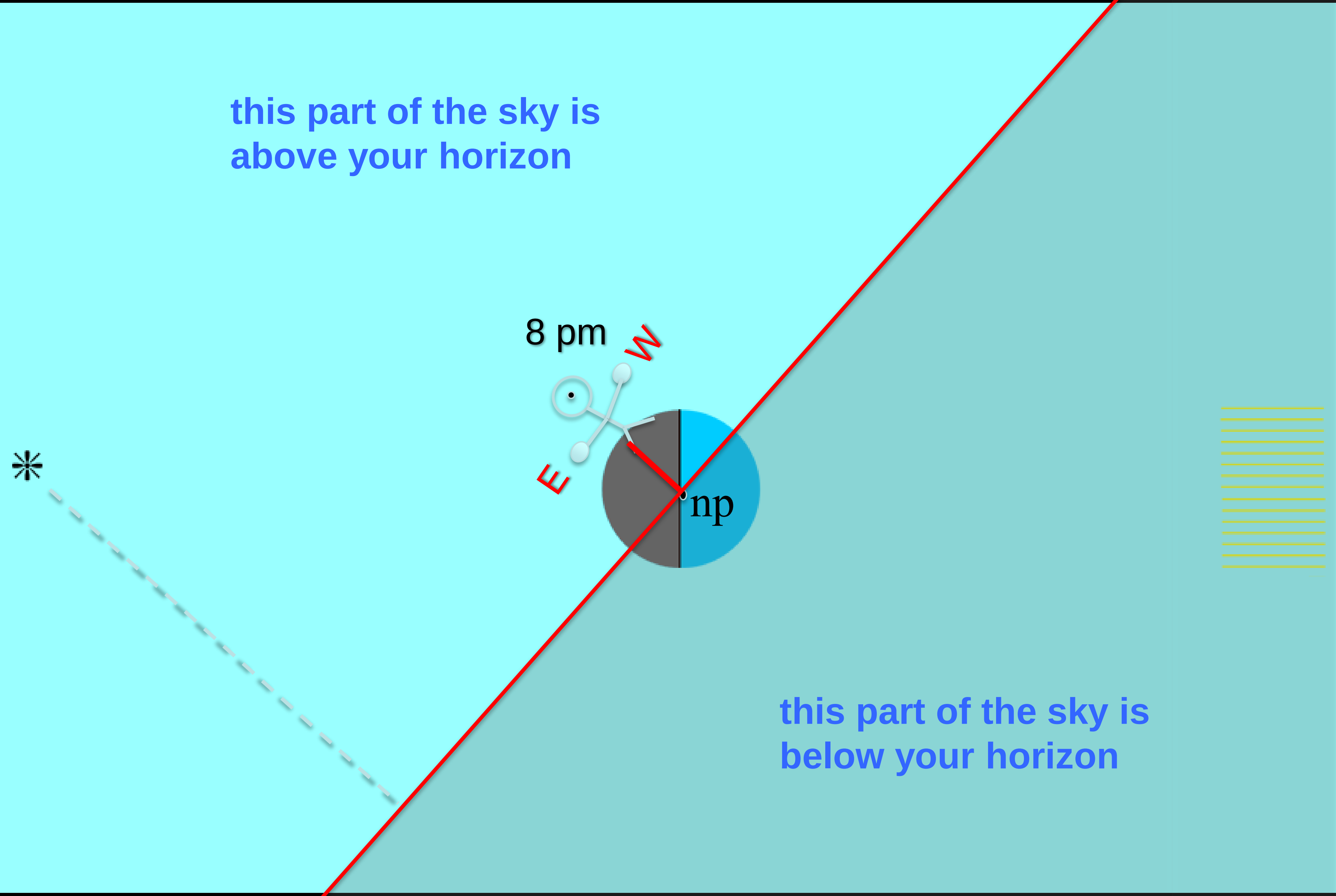


Can you see the star at sunset?

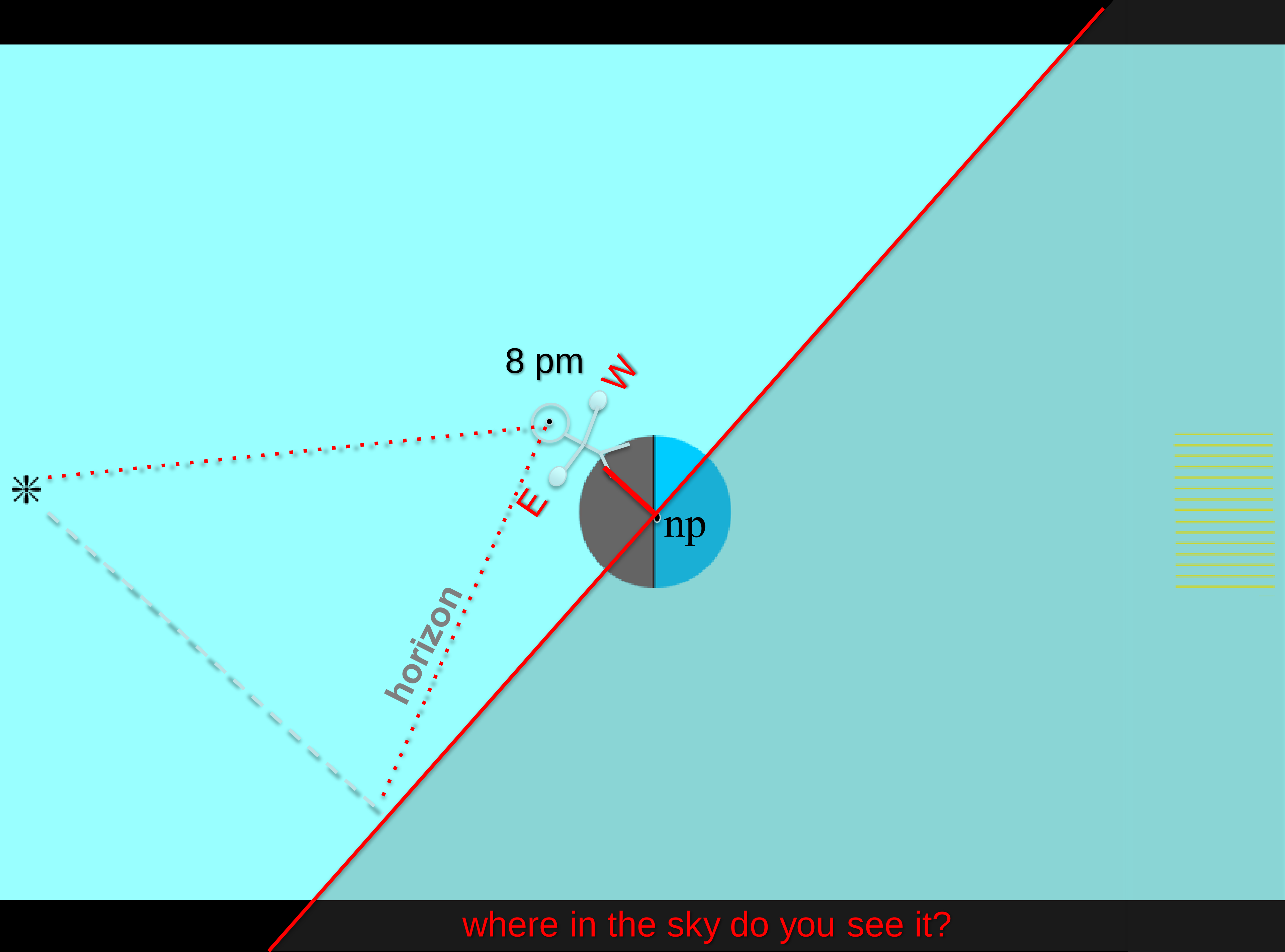


can you see the star at 8 pm?

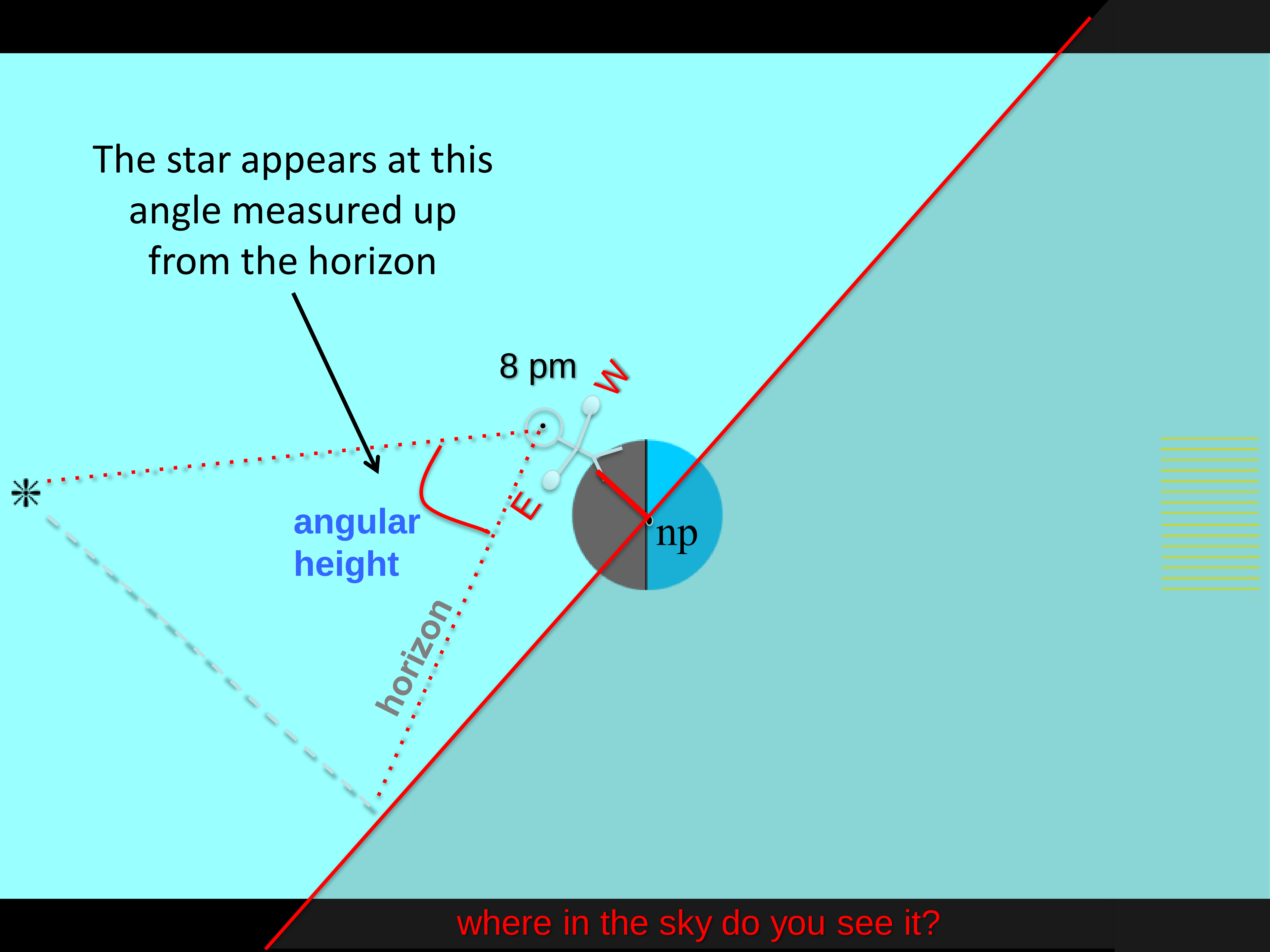

this part of the sky is
above your horizon
i.e. you can see the
star at 8 pm
8 pm
np
this part of the sky is
below your horizon
can you see the star at 8 pm?



where in the sky do you see it?

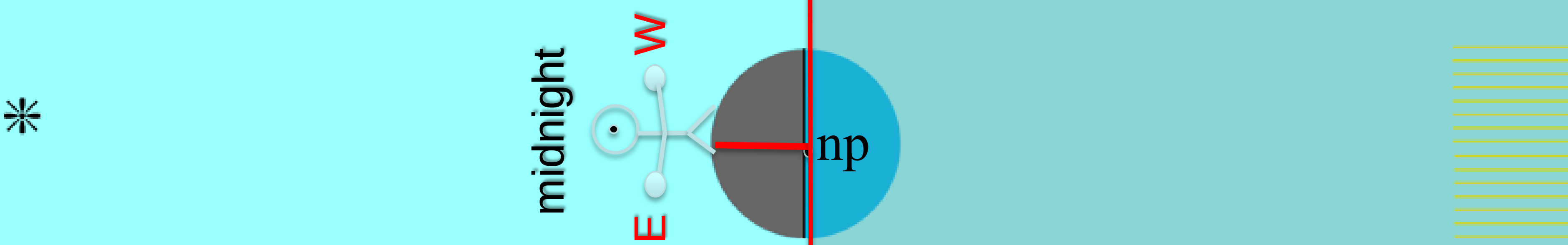


where in the sky do you see it?



The star appears at this angle measured up from the horizon
8 pm
W
E
angular height
horizon
np
where in the sky do you see it?

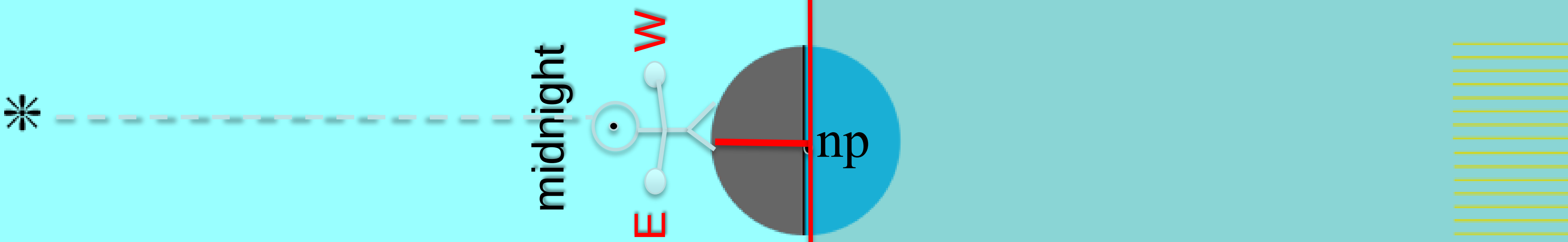
this part of the sky is
above your horizon



this part of the sky is
below your horizon —
you can't see it

Where is the star at midnight?

this part of the sky is
above your horizon



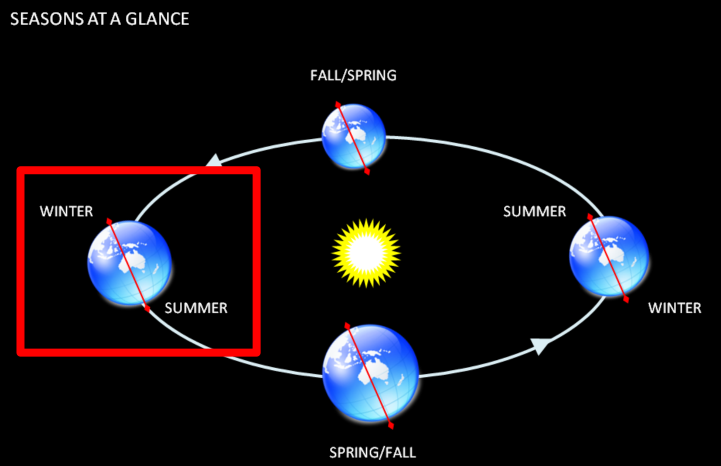
The star appears straight overhead (i.e. at an angle of 90° measured up from the horizon)

this part of the sky is
below your horizon —
you can't see it

Where is the star at midnight?

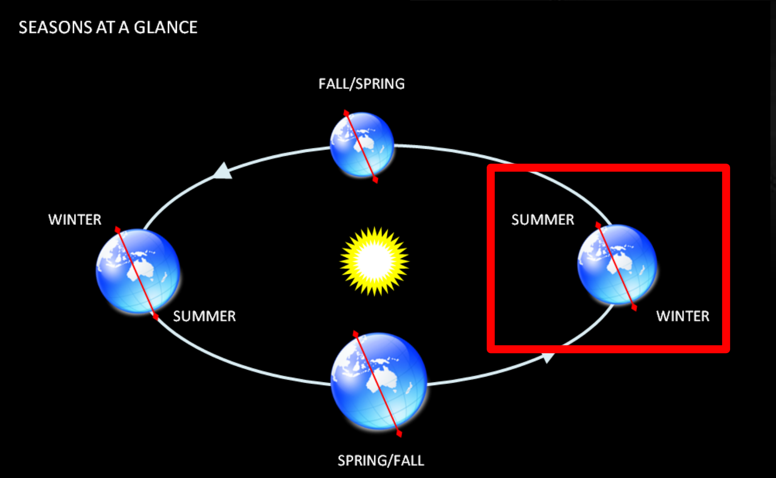
Not only do you see different stars over the course of the night, but over the seasons too

(since the night sky faces different directions [slide 86])

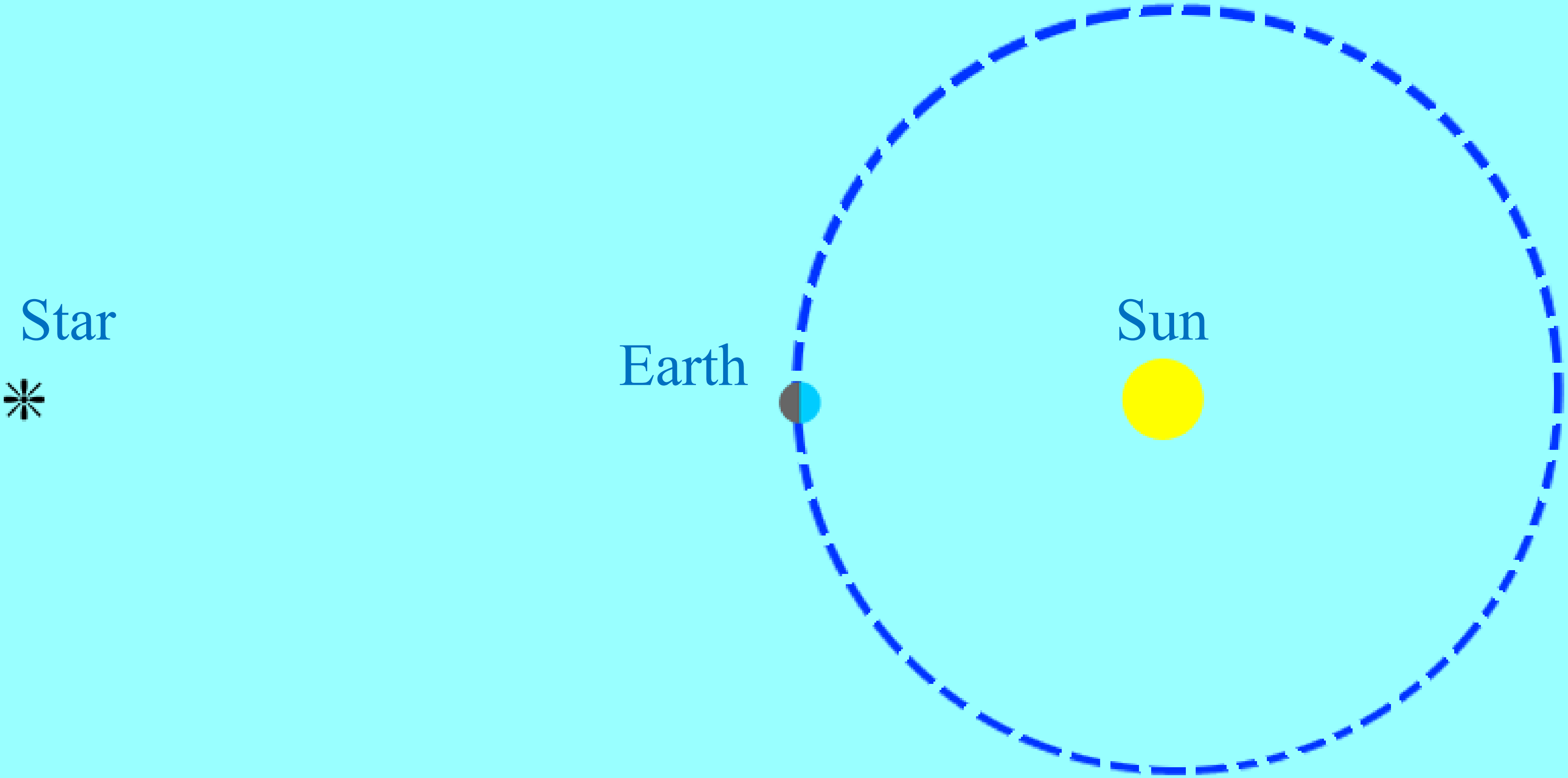


CREDIT: B.W. MCGEE © 2013

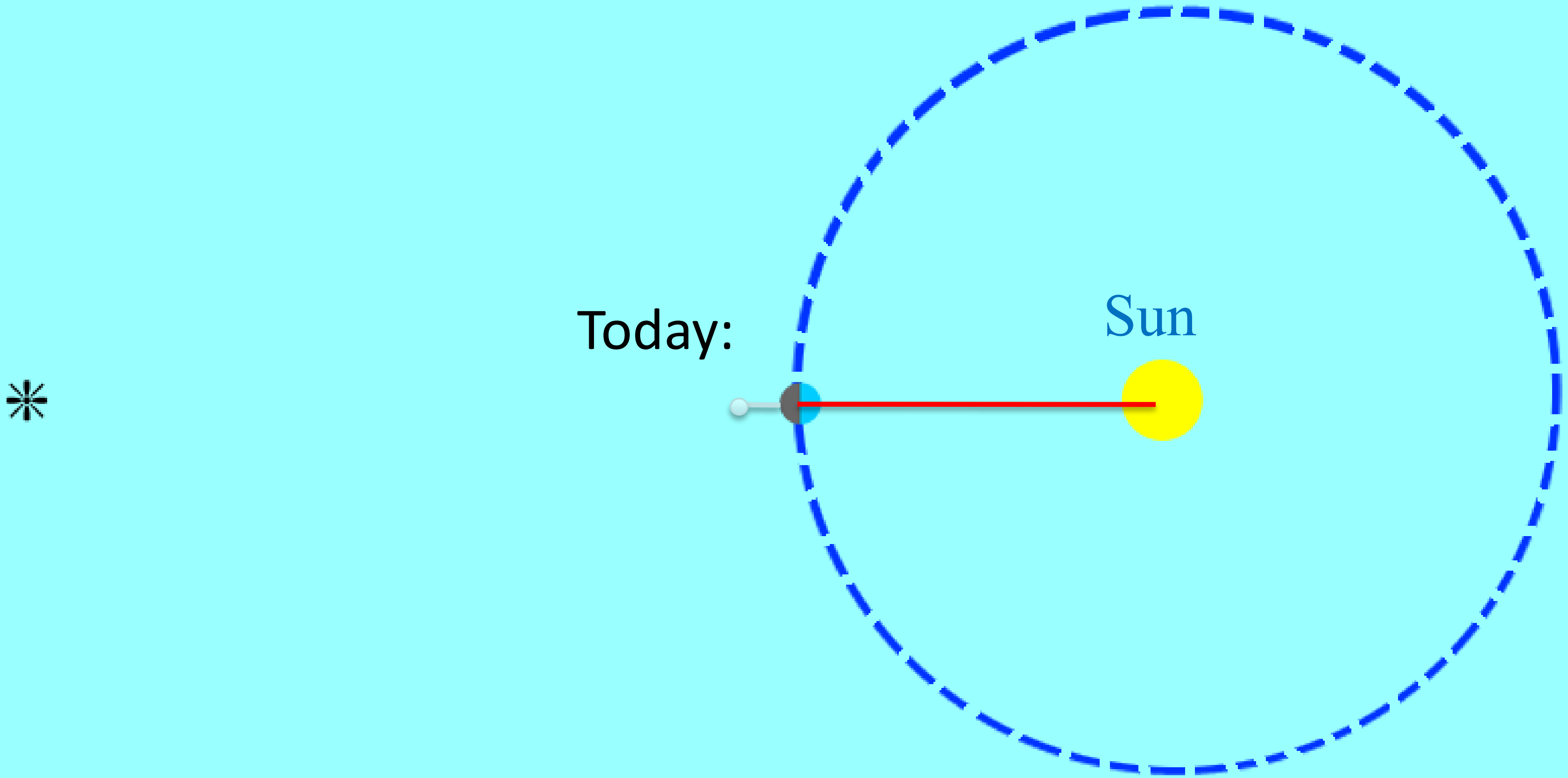
e.g. Orion in Northern Winter



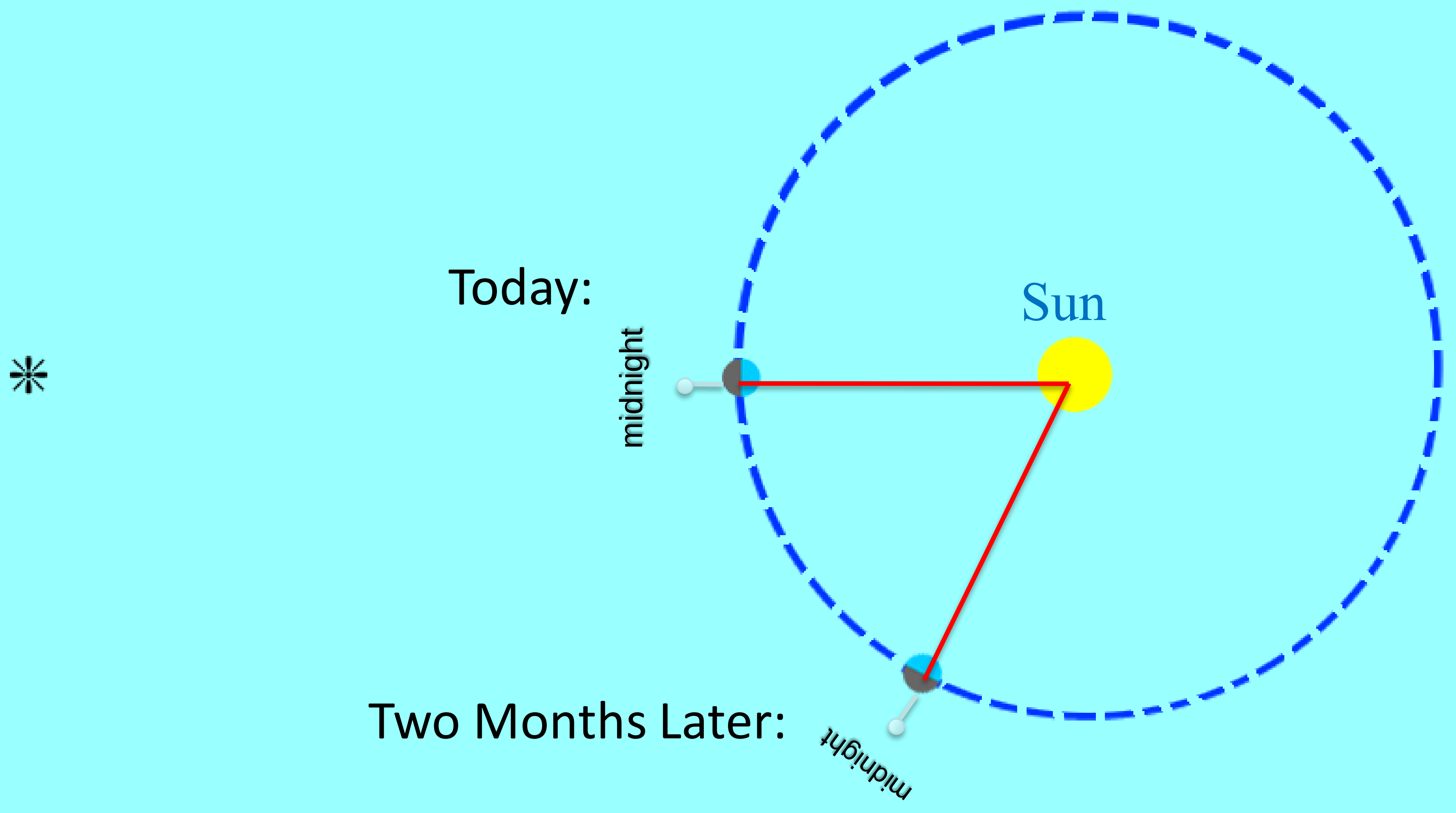
and, Sagittarius in Northern Summer



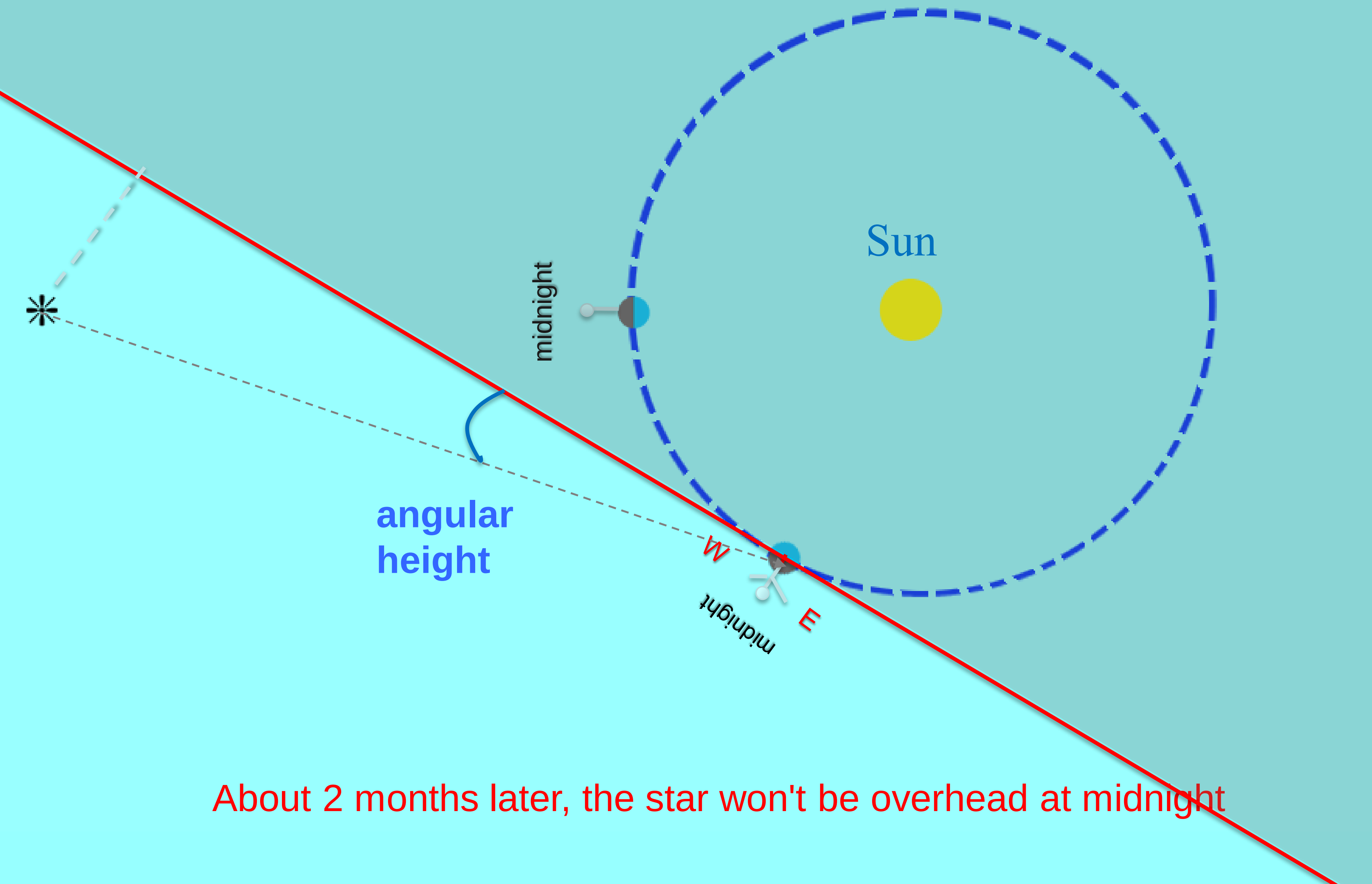
When and where you see a given star also depends on Earth's orbital position around the Sun



When and where you see a given star also depends on Earth's orbital position around the Sun



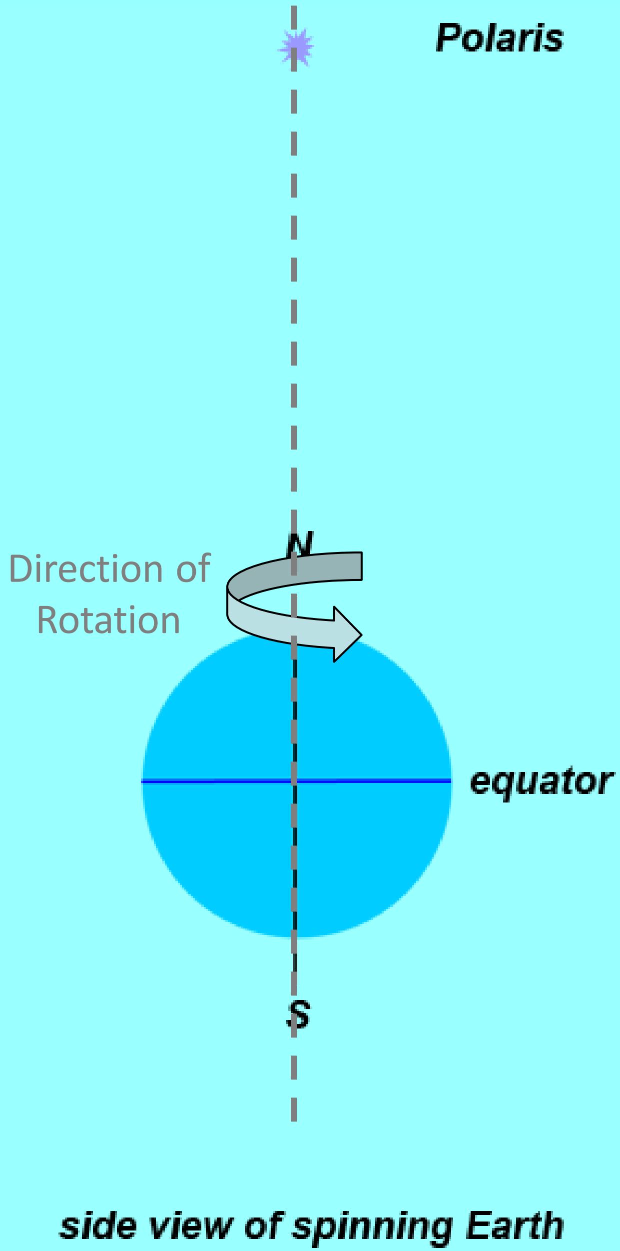
About 2 months later, the star won't be overhead at midnight
(because the earth has moved to a different position with respect to the sun)



About 2 months later, the star won't be overhead at midnight

Position of Polaris:

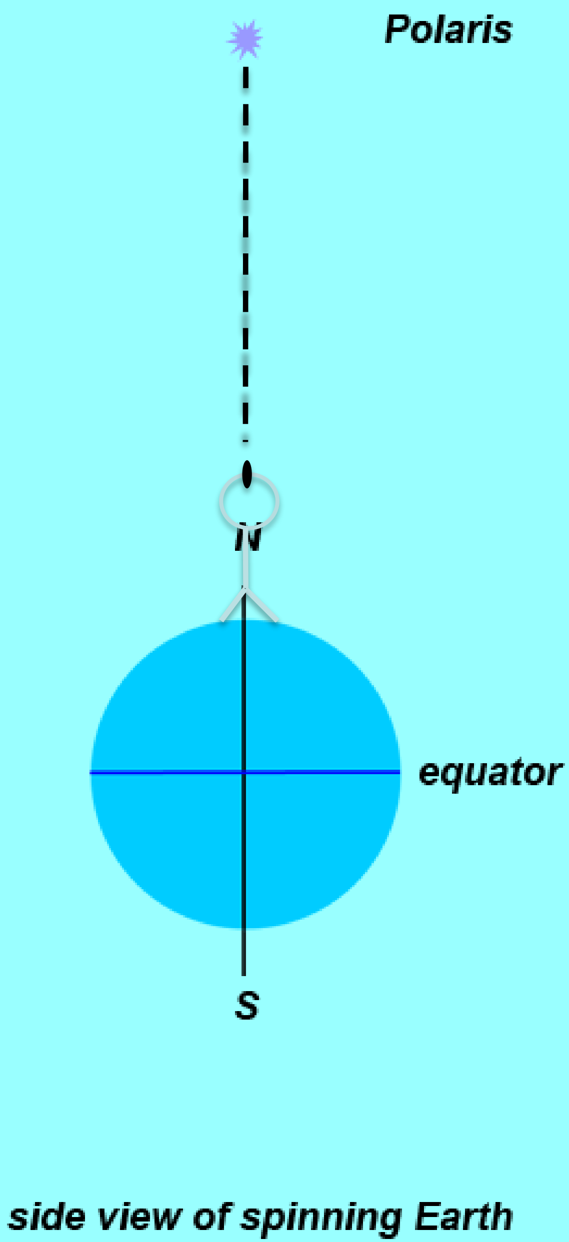
Polaris (i.e. the north star) lies on the extension of the earth's N-S axis



Position of Polaris:

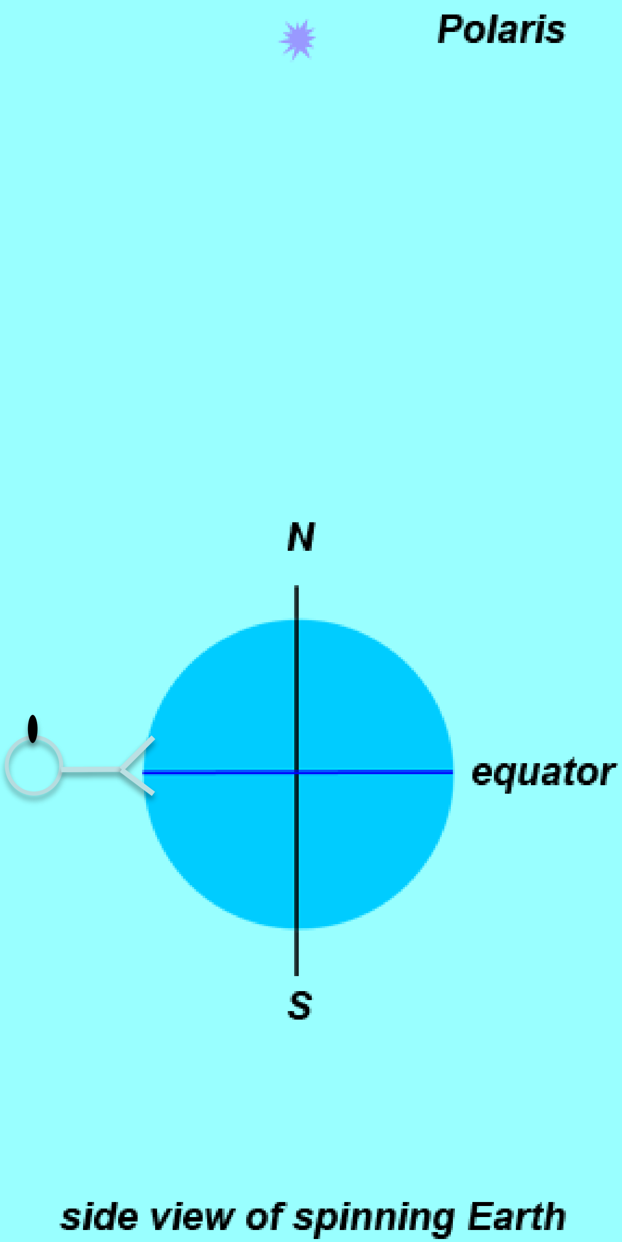
Observer at North Pole

Polaris appears overhead

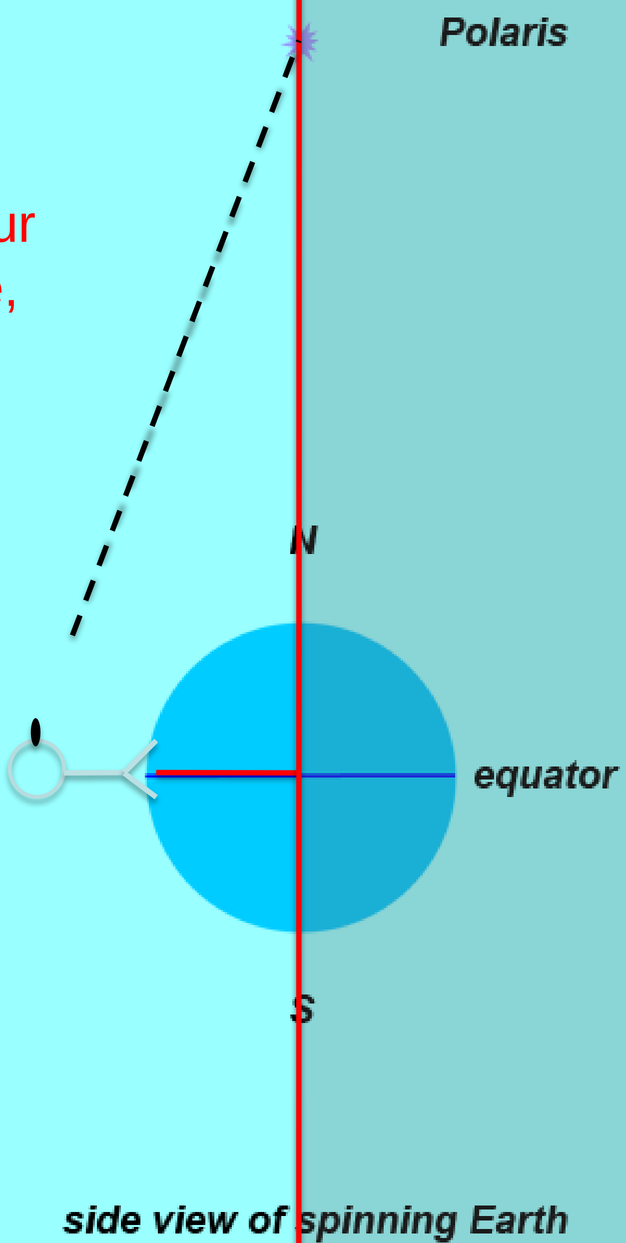


Position of Polaris:
Observer at Equator

Polaris appears at horizon



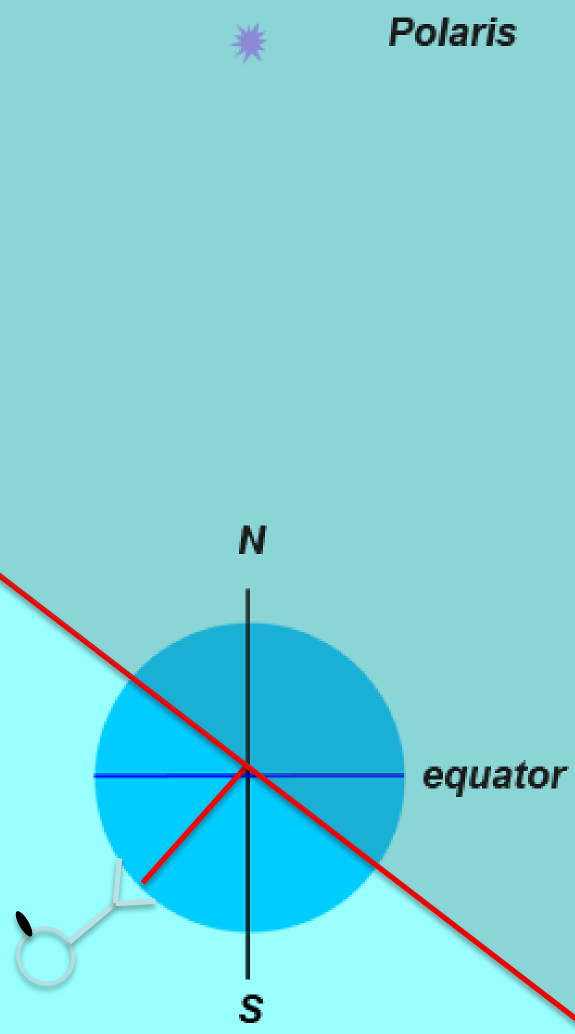
Polaris would be on your horizon— barely visible, if at all.



Position of Polaris:
Observer in Southern Hemisphere

Polaris not visible

Below the equator, Polaris would NEVER be visible

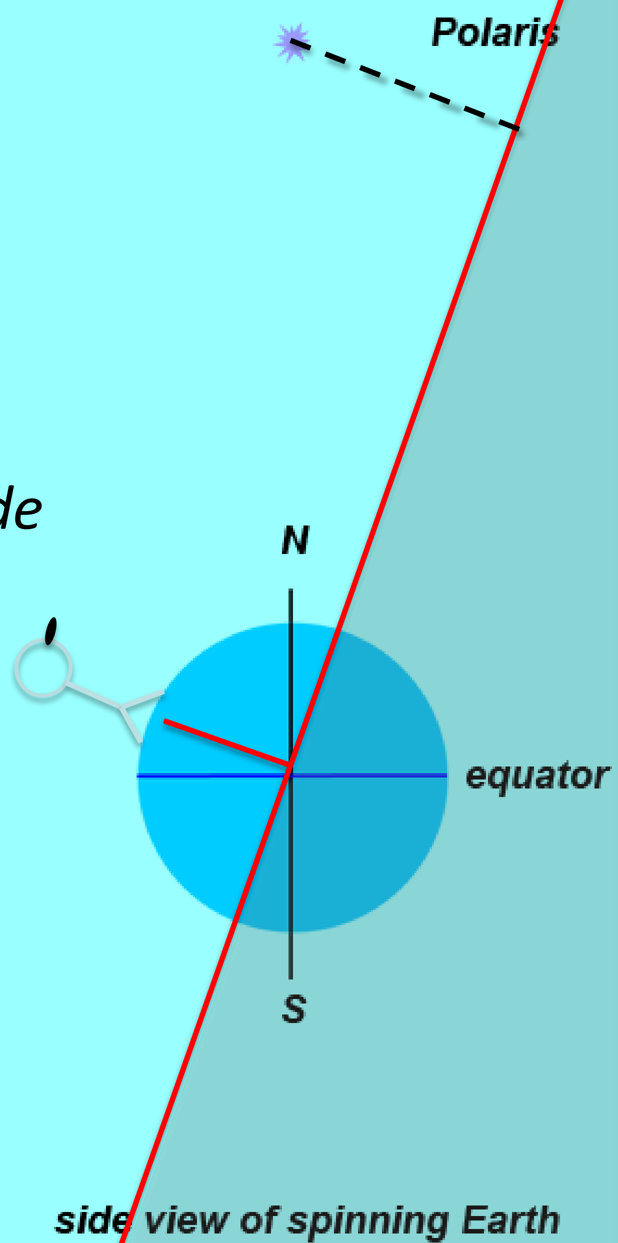


side view of spinning Earth

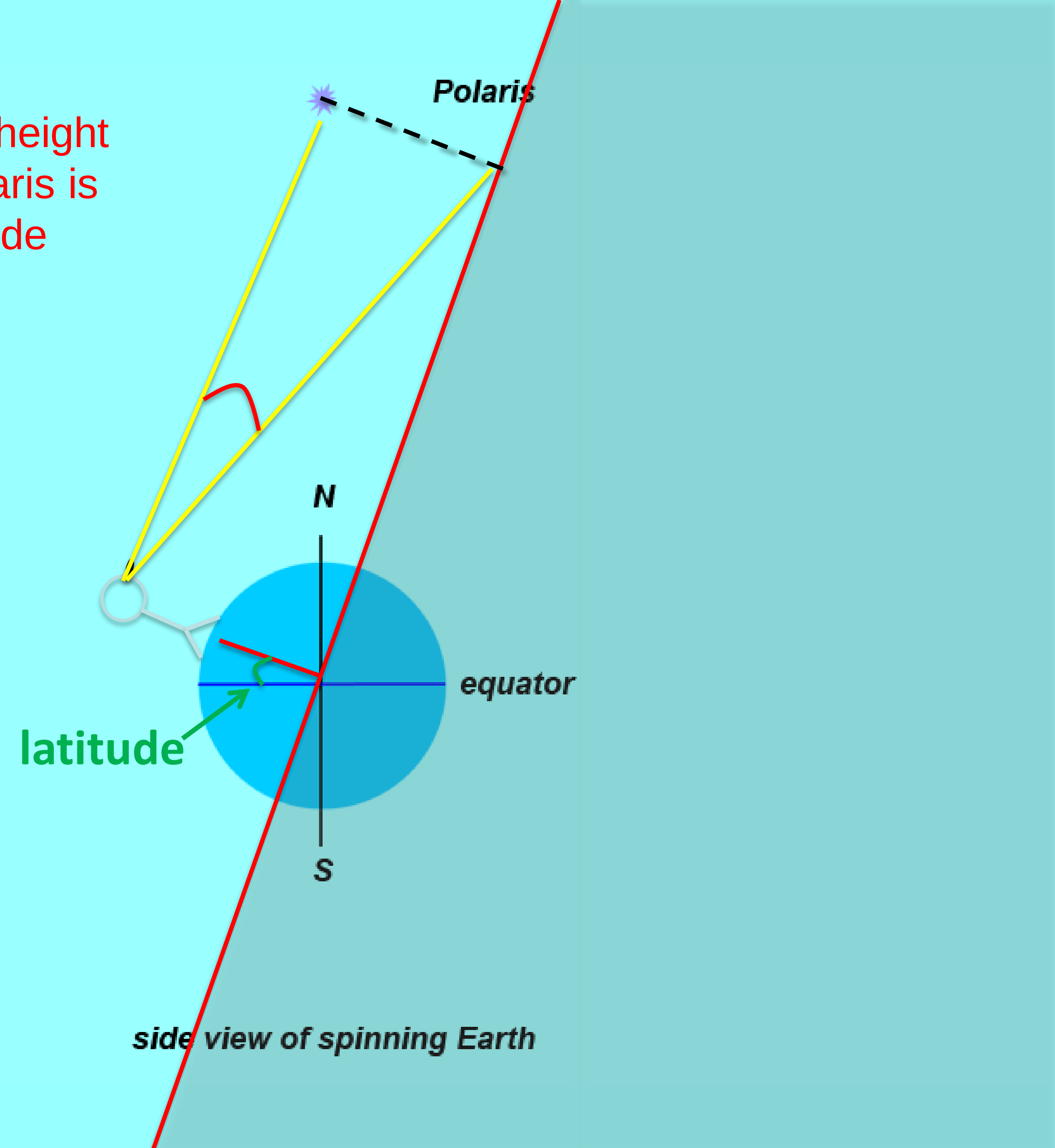
Position of Polaris:
Observer in Northern Hemisphere

Polaris appears at an angular height that depends on the *latitude* of the observer

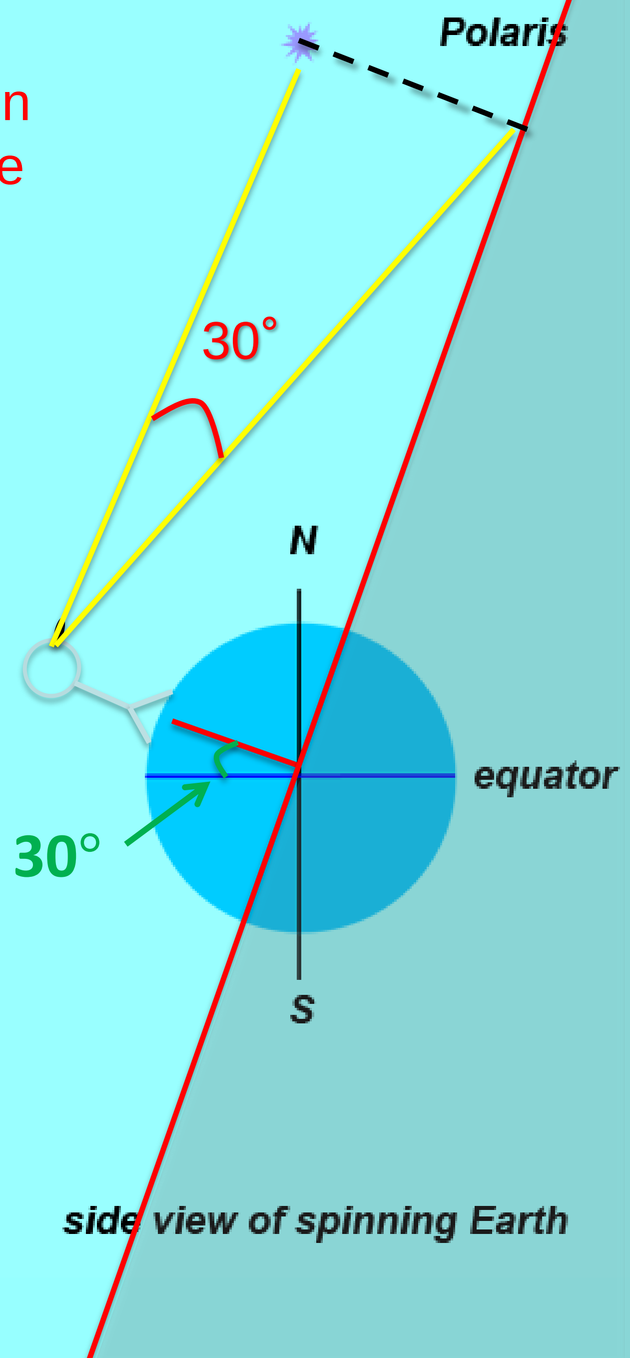
Between the NP and the equator, you would see Polaris at your latitude above the North horizon

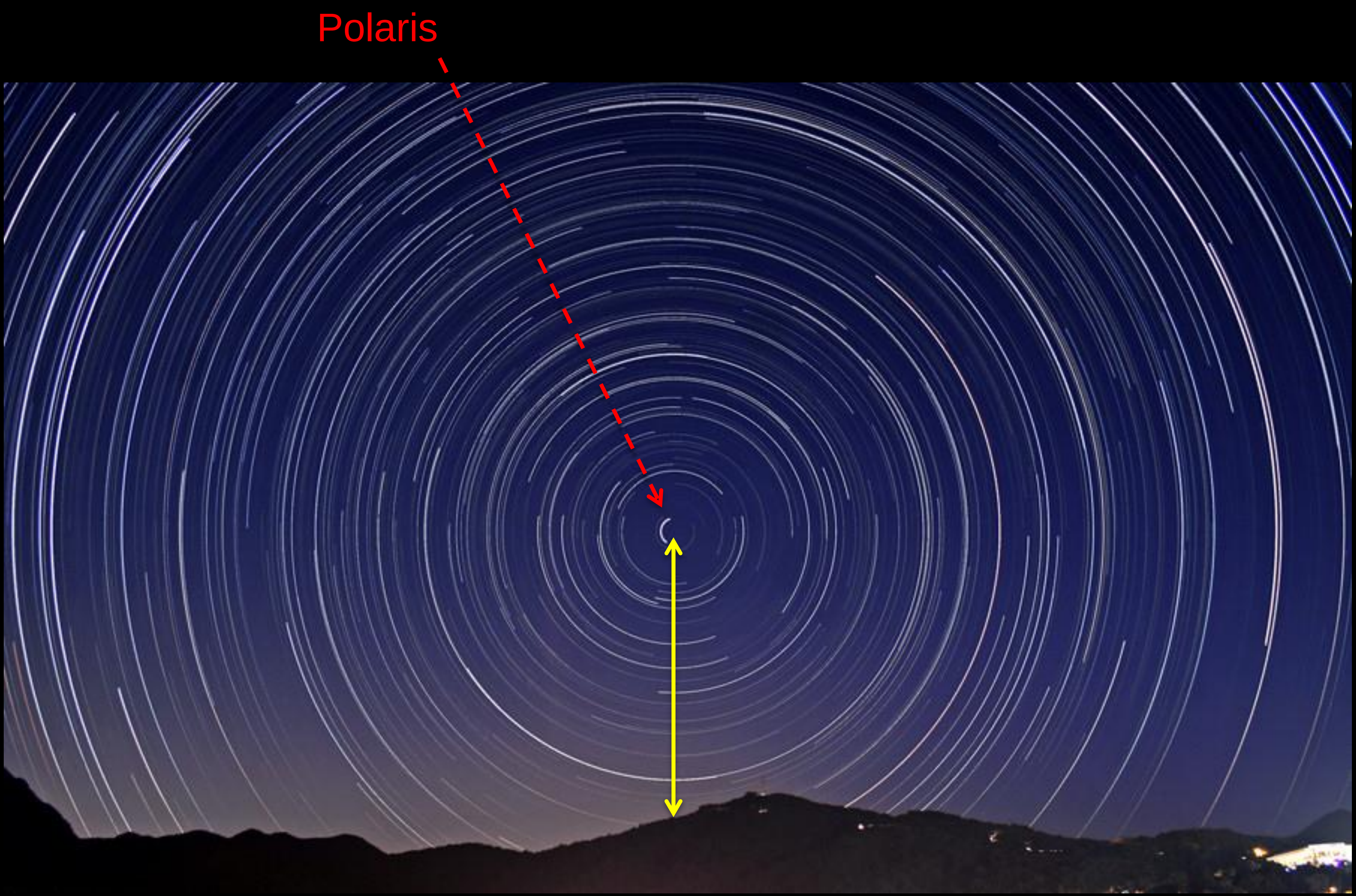


The angular height you see Polaris is your latitude



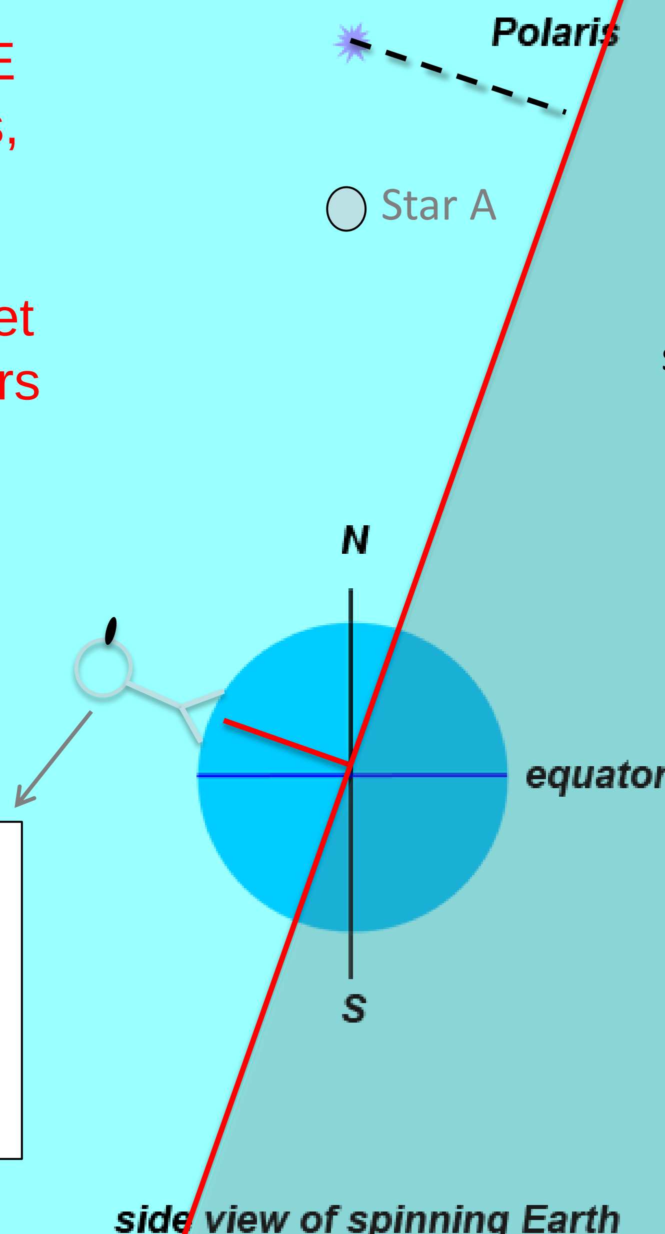
e.g. if your latitude on Earth is 30°, then the angular height of Polaris is also 30°





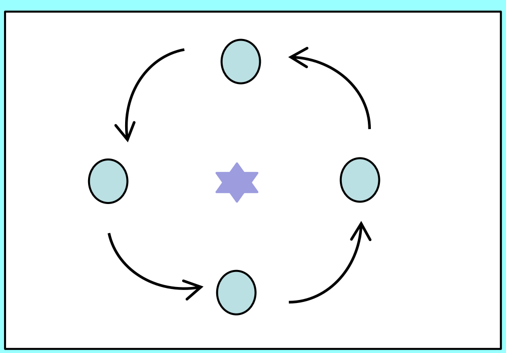
Observer's view of North horizon:
Polaris remains at fixed position throughout the night

But for latitudes ABOVE the equator, some stars, within your latitude in angle between Polaris and the horizon never set — **CIRCUMPOLAR** stars



Star A is a circumpolar star that does not set and appears to rotate around Polaris

Observer's view:
Polaris remains fixed at center and Star A rotates around it during the course of the night



Observer’s view of North horizon

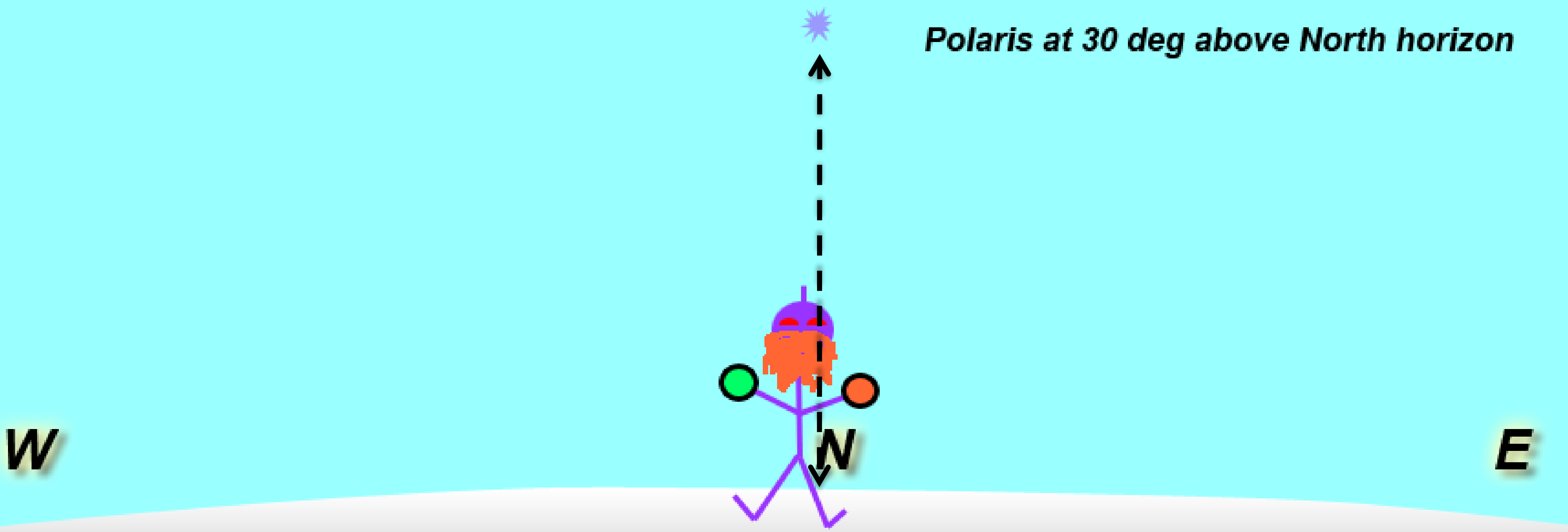
Observer’s view of North horizon:
Polaris remains at fixed position whereas circumpolar stars rotate around it

[Time-lapse Video Clip of Rotating Milky Way]

face NORTH


Polaris at 30 deg above North horizon
W
N
E
at Valdosta, Georgia, USA
latitude 30 deg

face NORTH



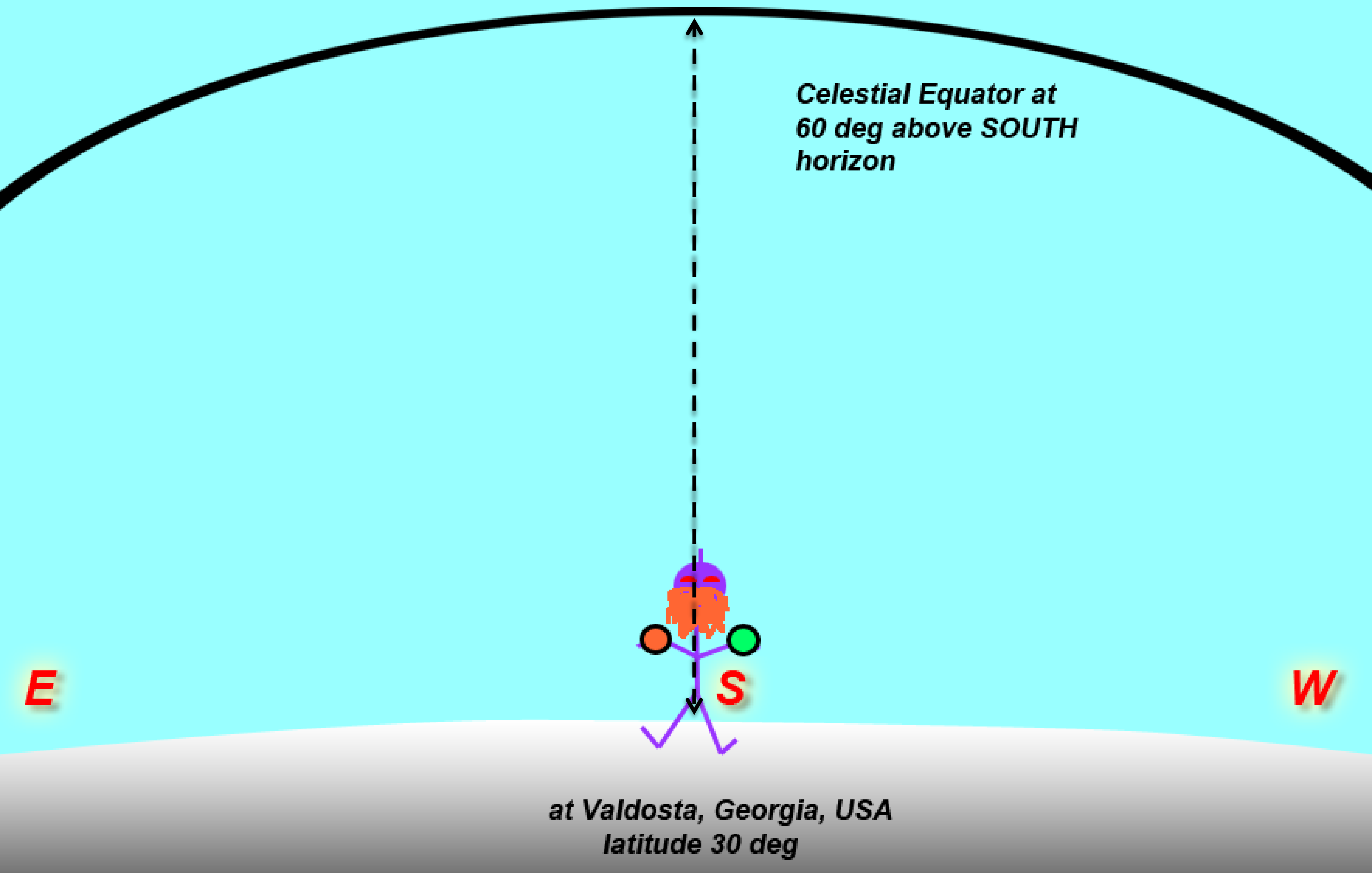
at Valdosta, Georgia, USA
latitude 30 deg

Over the course of an evening

stars within 30 deg of Polaris do not set — these are CIRCUMPOLAR stars

stars within 30 deg of Polaris do not set — these are CIRCUMPOLAR stars

Now face SOUTH

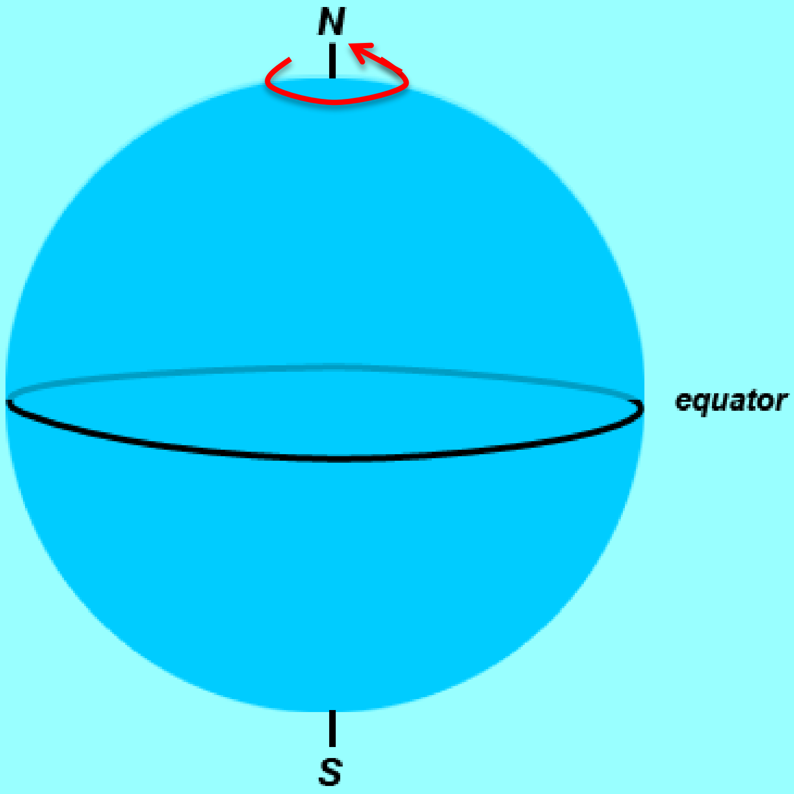


Facing SOUTH EAST over the course of an evening

Facing SOUTH-EAST — star trails that are straight show part of the celestial equator that will arc over the sky as you face due south

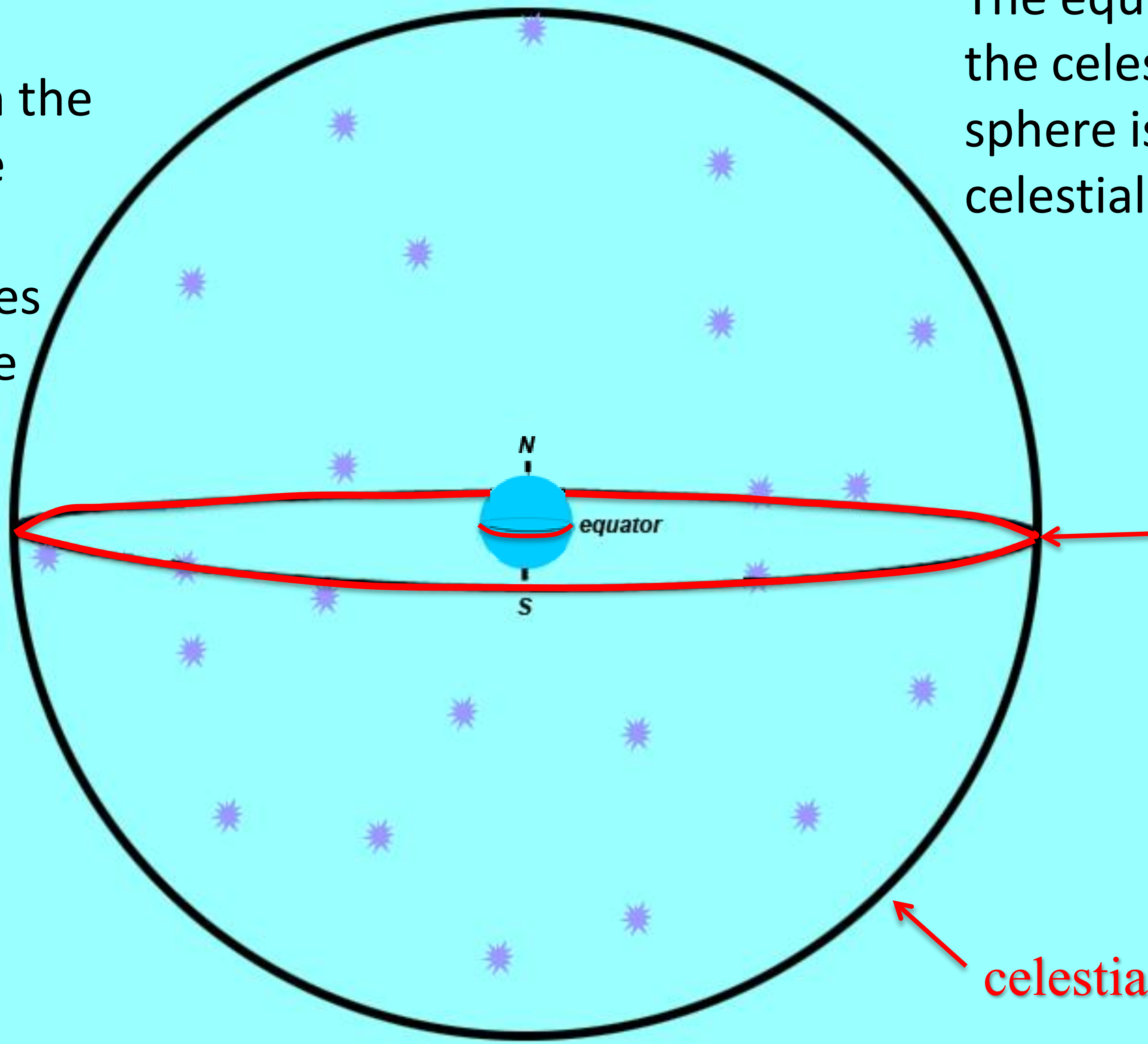

The Ecliptic Plane

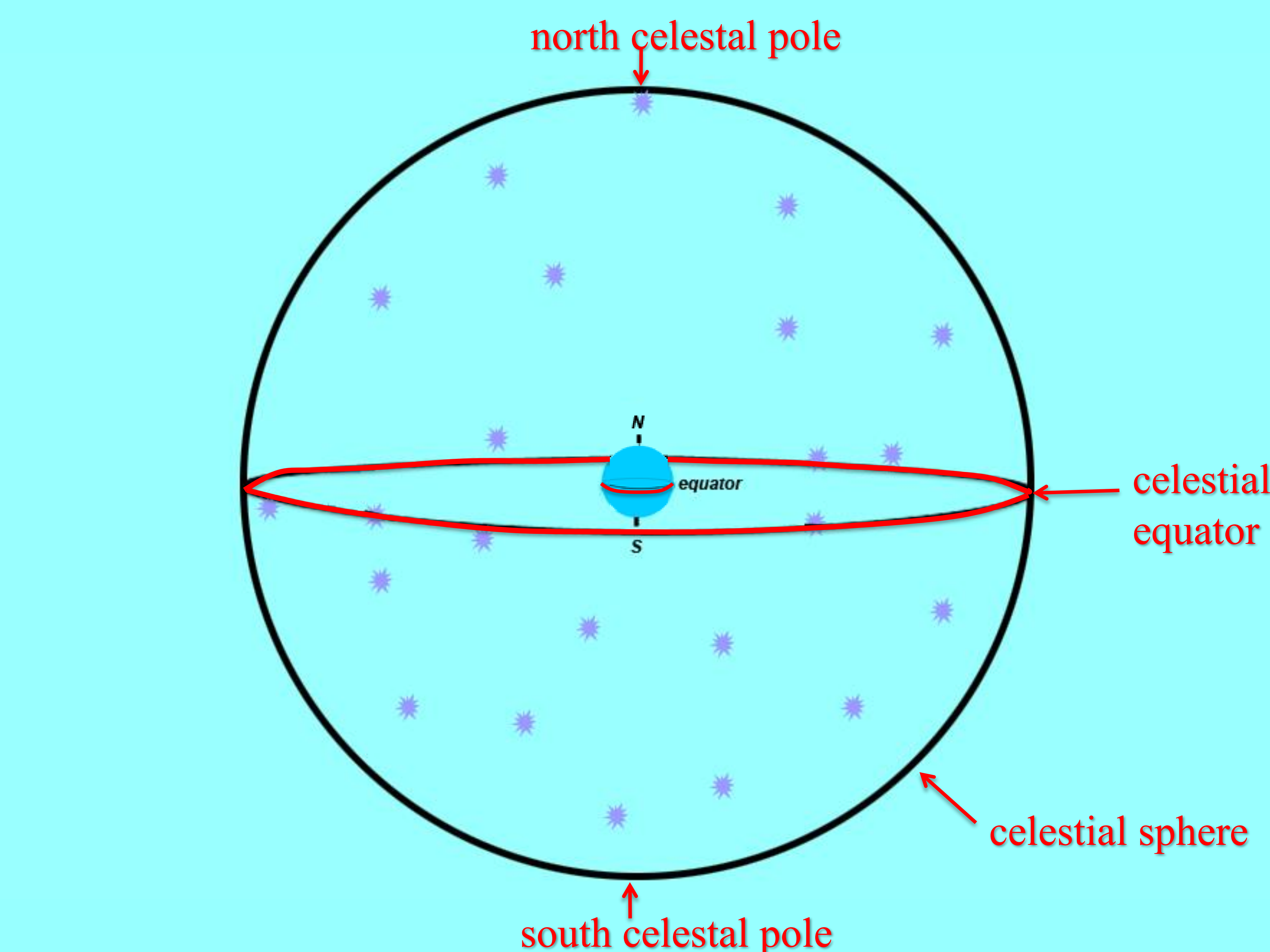
Side view of earth:

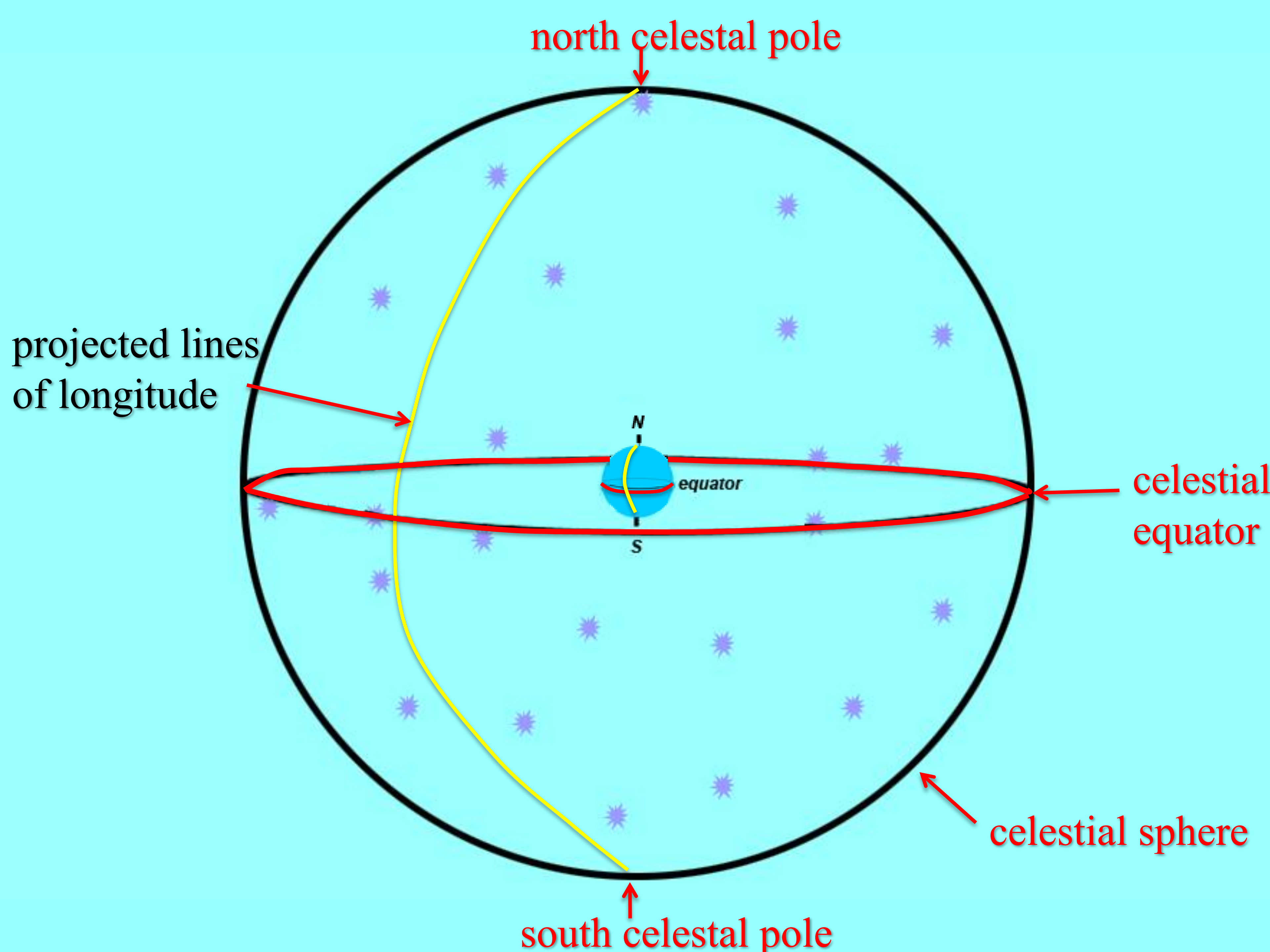


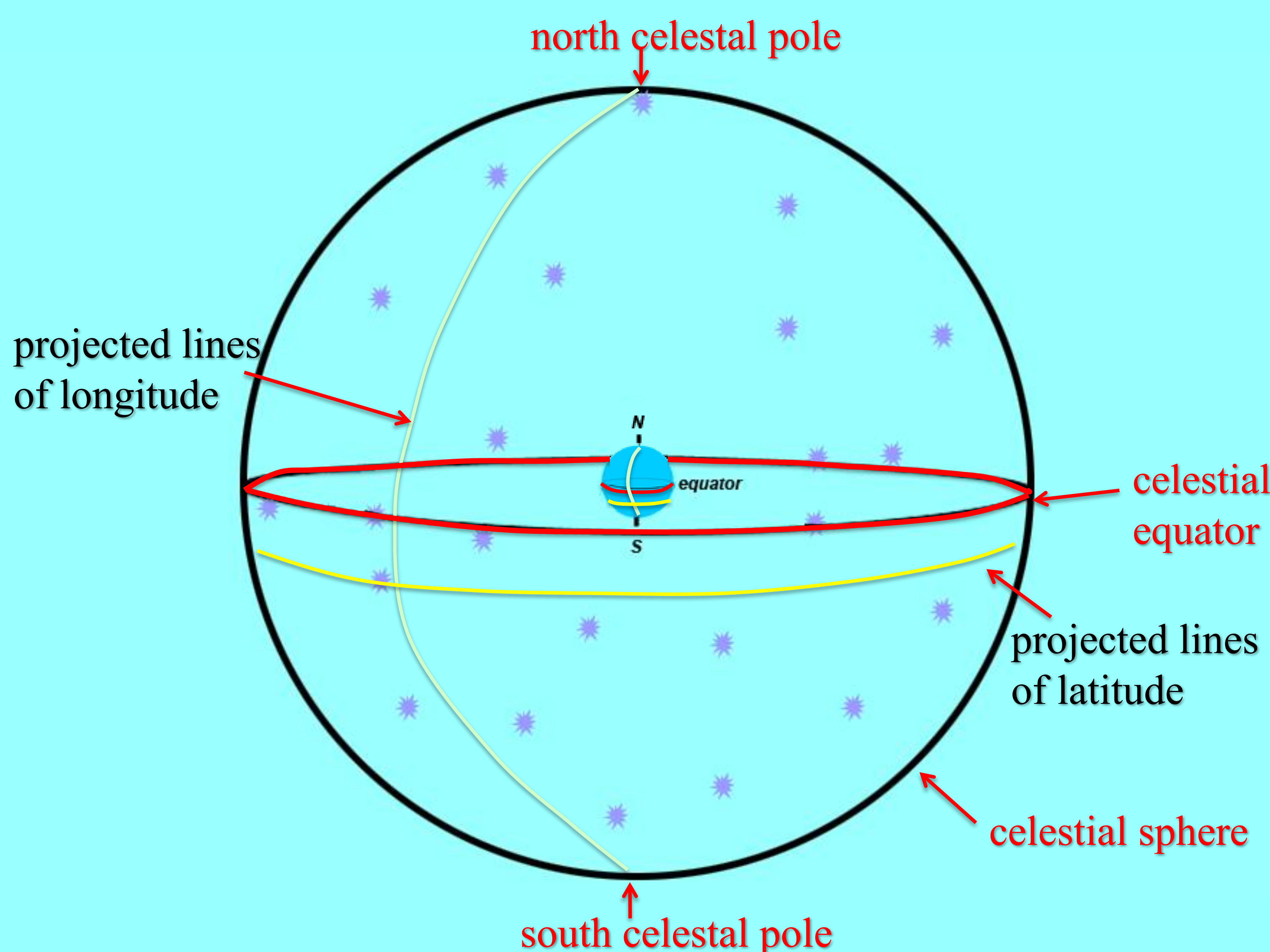
Draw an imaginary sphere with the earth at the center that encompasses the universe

The equator of the celestial sphere is the celestial equator

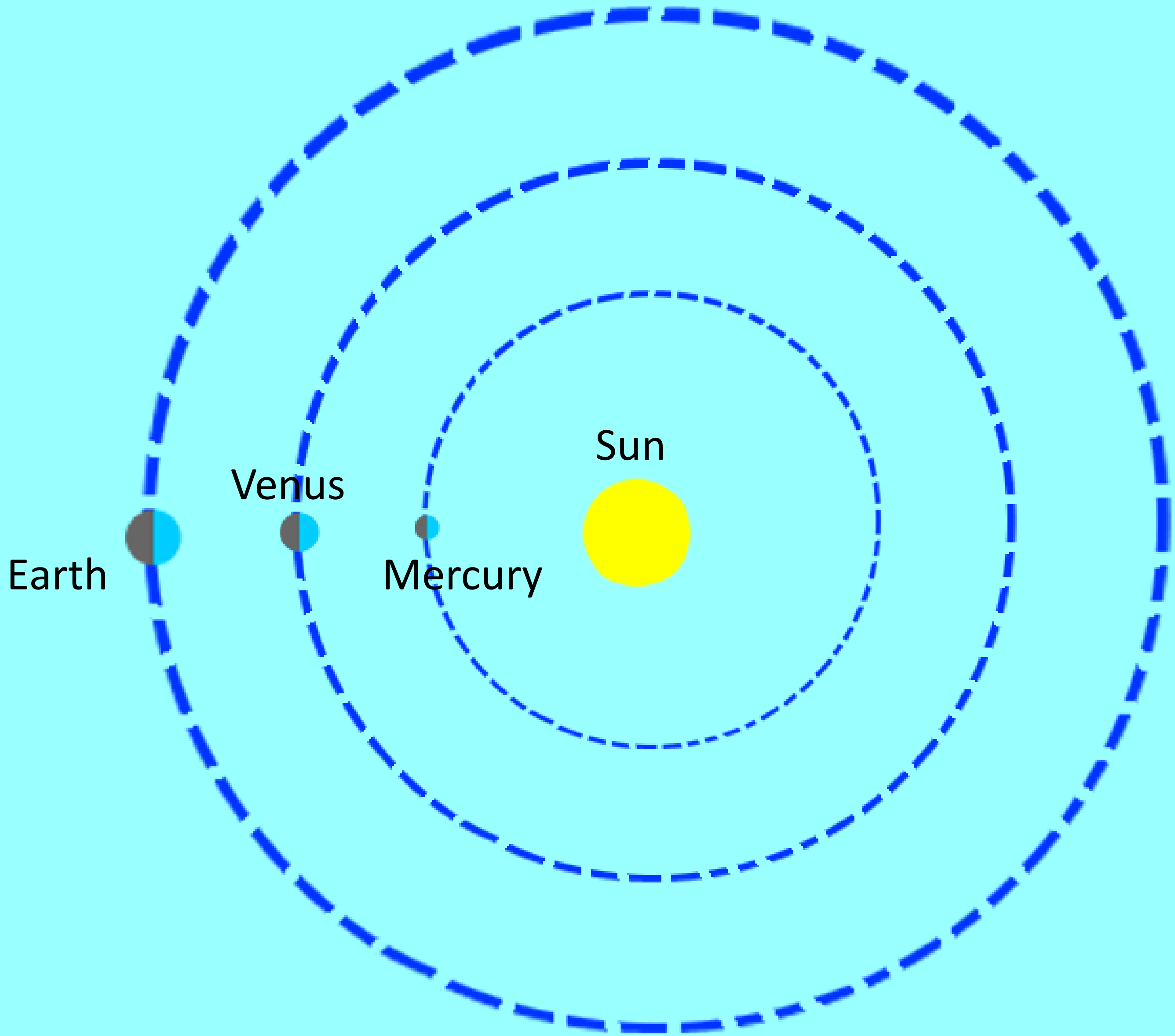



north celestal pole
N
equator
S
celestial
equator
celestial sphere
south celestal pole

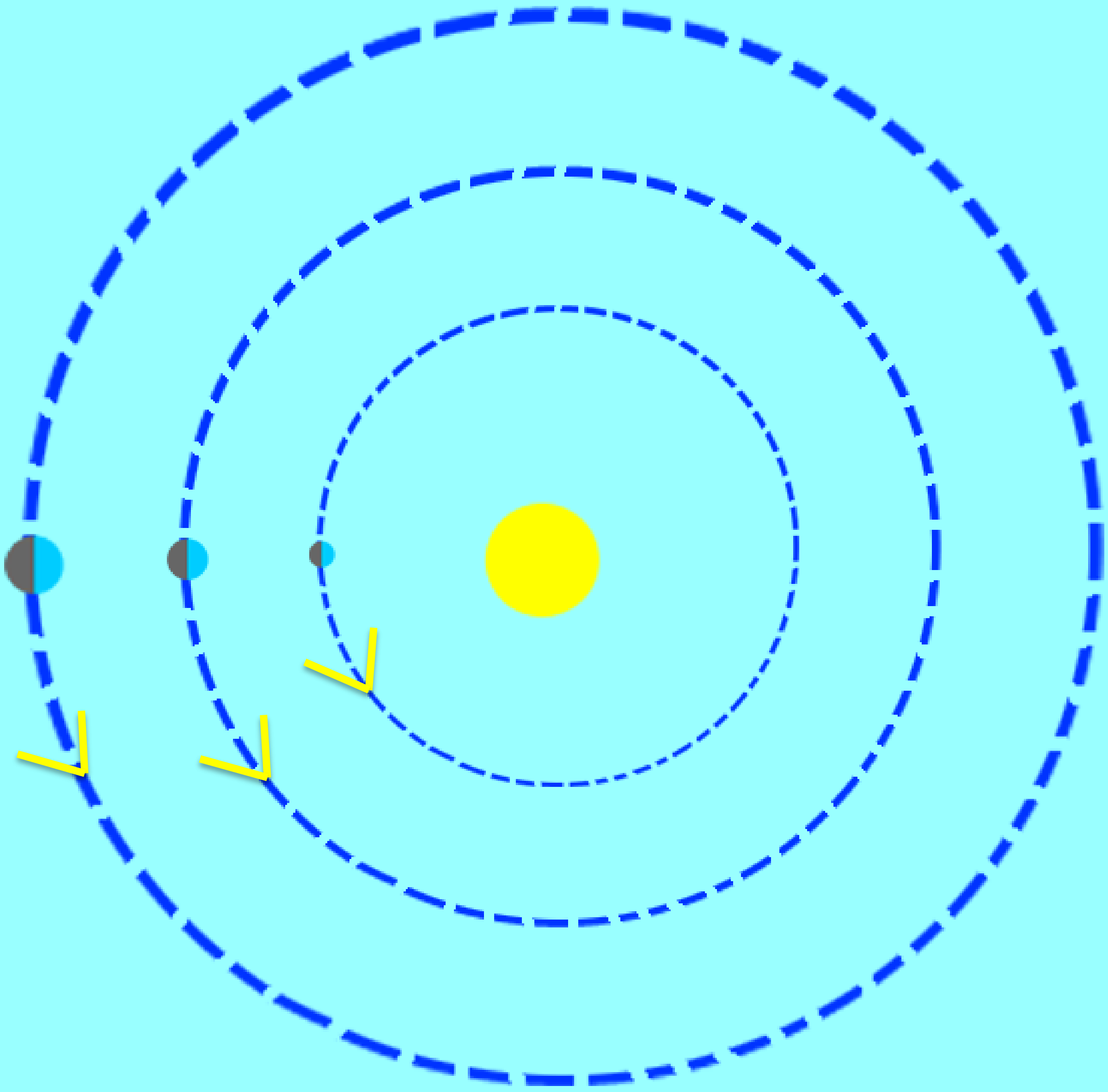

north celestial pole
projected lines of longitude
N
equator
celestial equator
S
celestial sphere
south celestial pole


north celestal pole
projected lines
of longitude
N
equator
S
celestial
equator
projected lines
of latitude
celestial sphere
south celestal pole

View looking down on **north pole** of earth



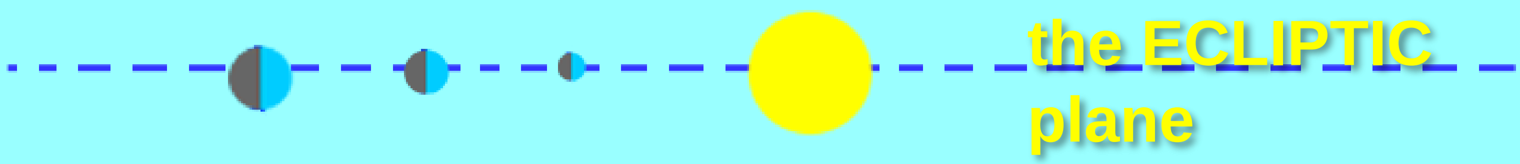
Motion of planets over the course of a year



All planets move counterclockwise

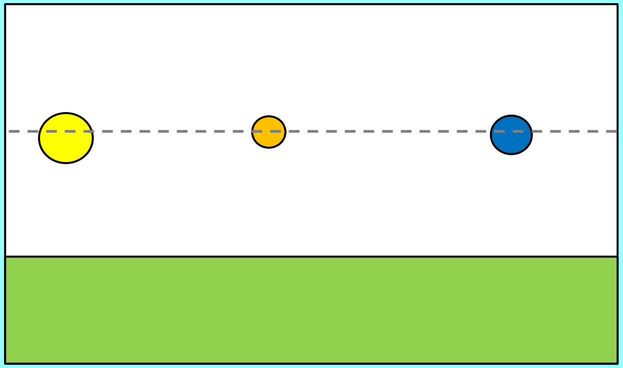
View looking **edge-on** to the solar system

planets are in plane — the ECLIPTIC plane

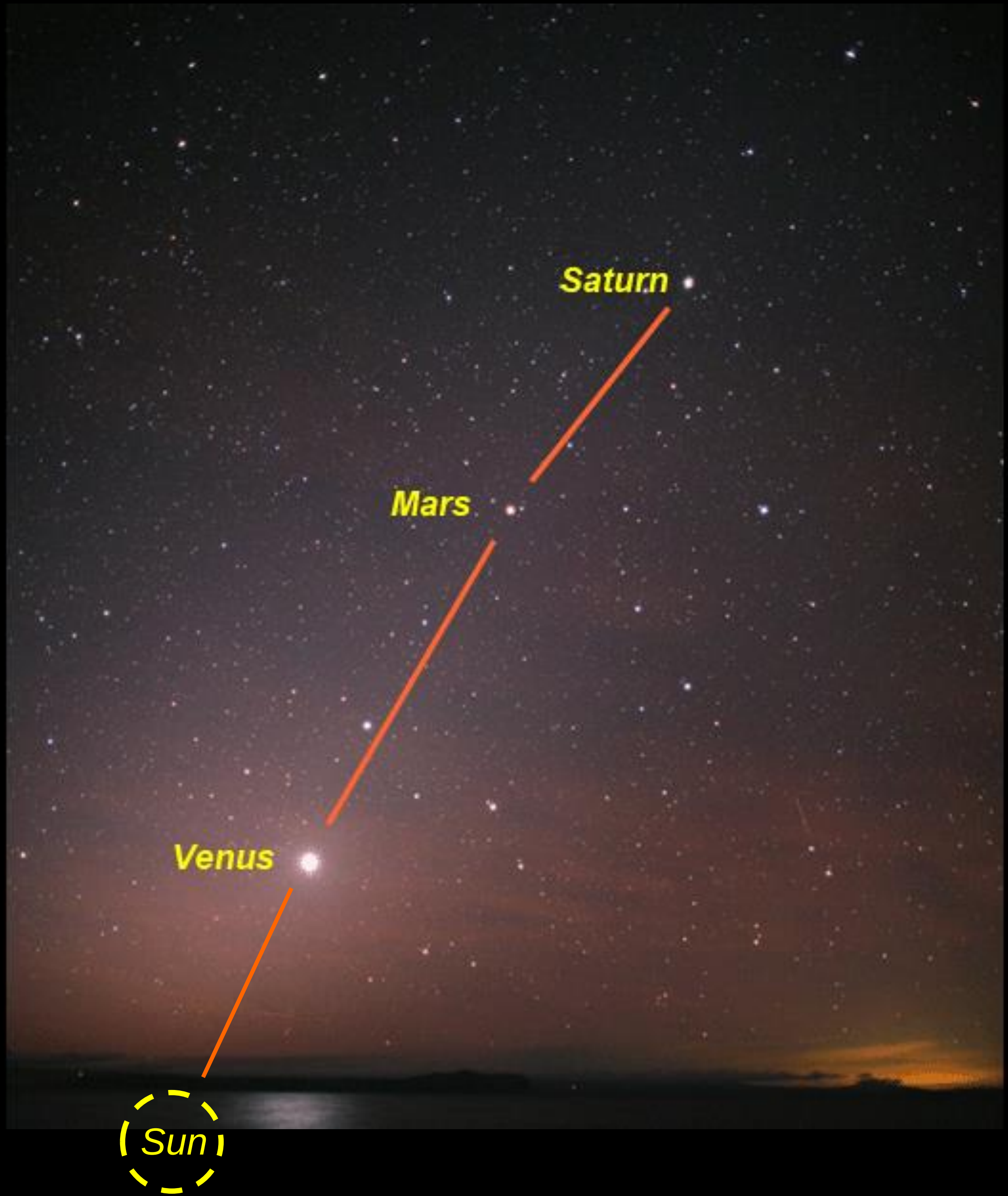


If the equator of the earth and the celestial equator lay on the same plane, an observer on earth would see the sun and the planets lie on a line parallel to the horizon

View from Earth:

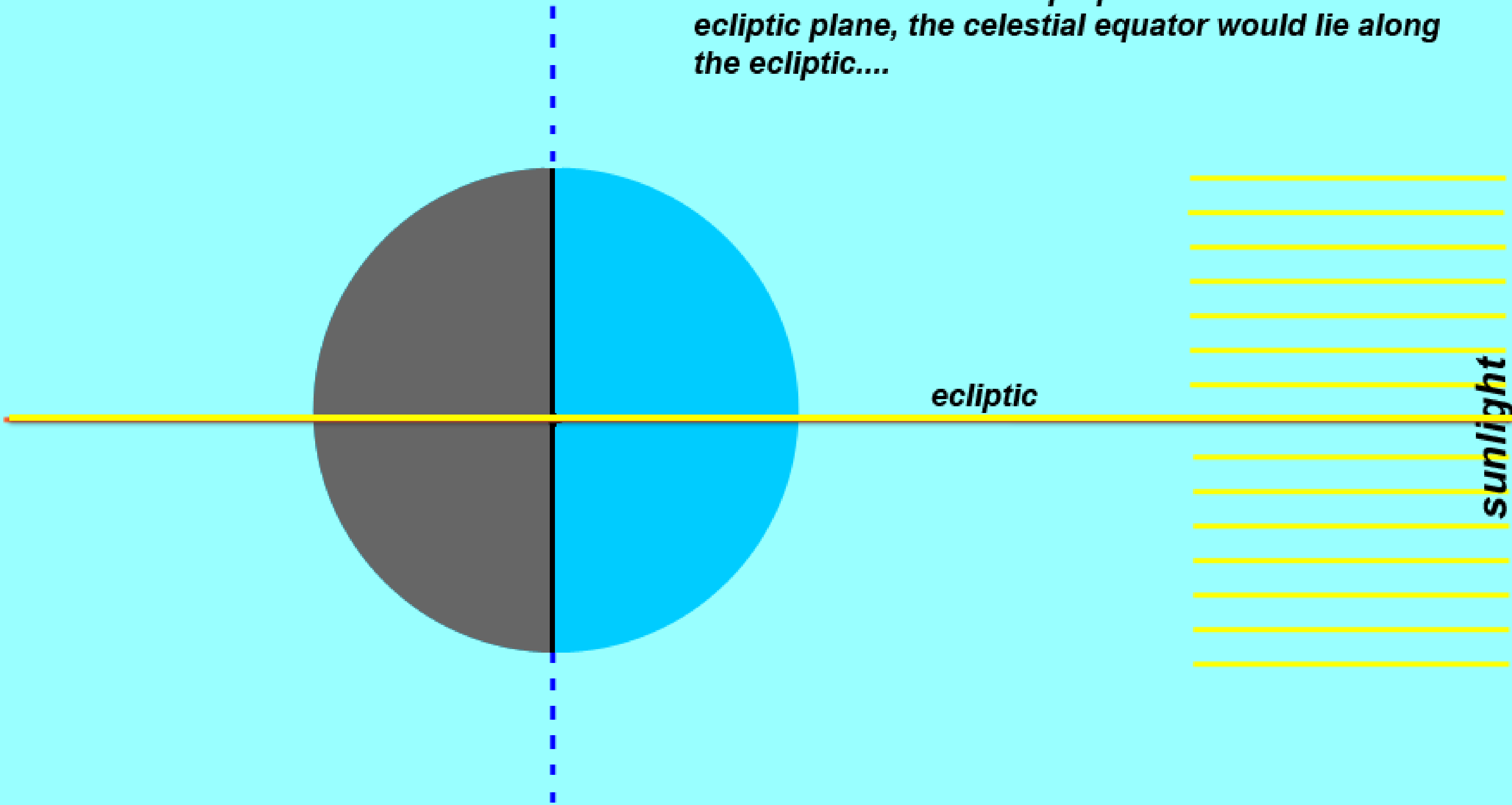


However, the view from the ground shows …

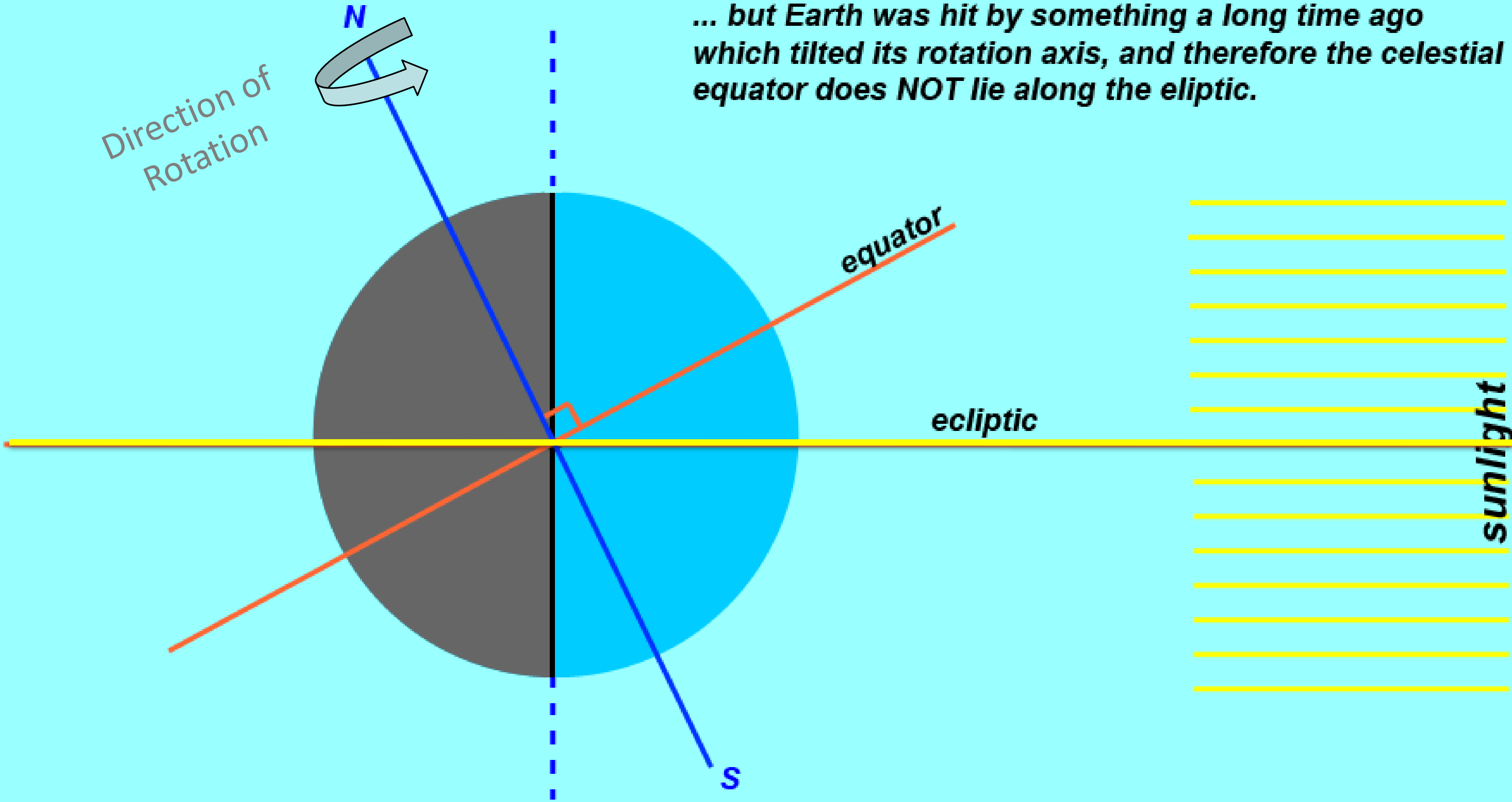


view from the ground: …the ECLIPTIC appearing like an arc

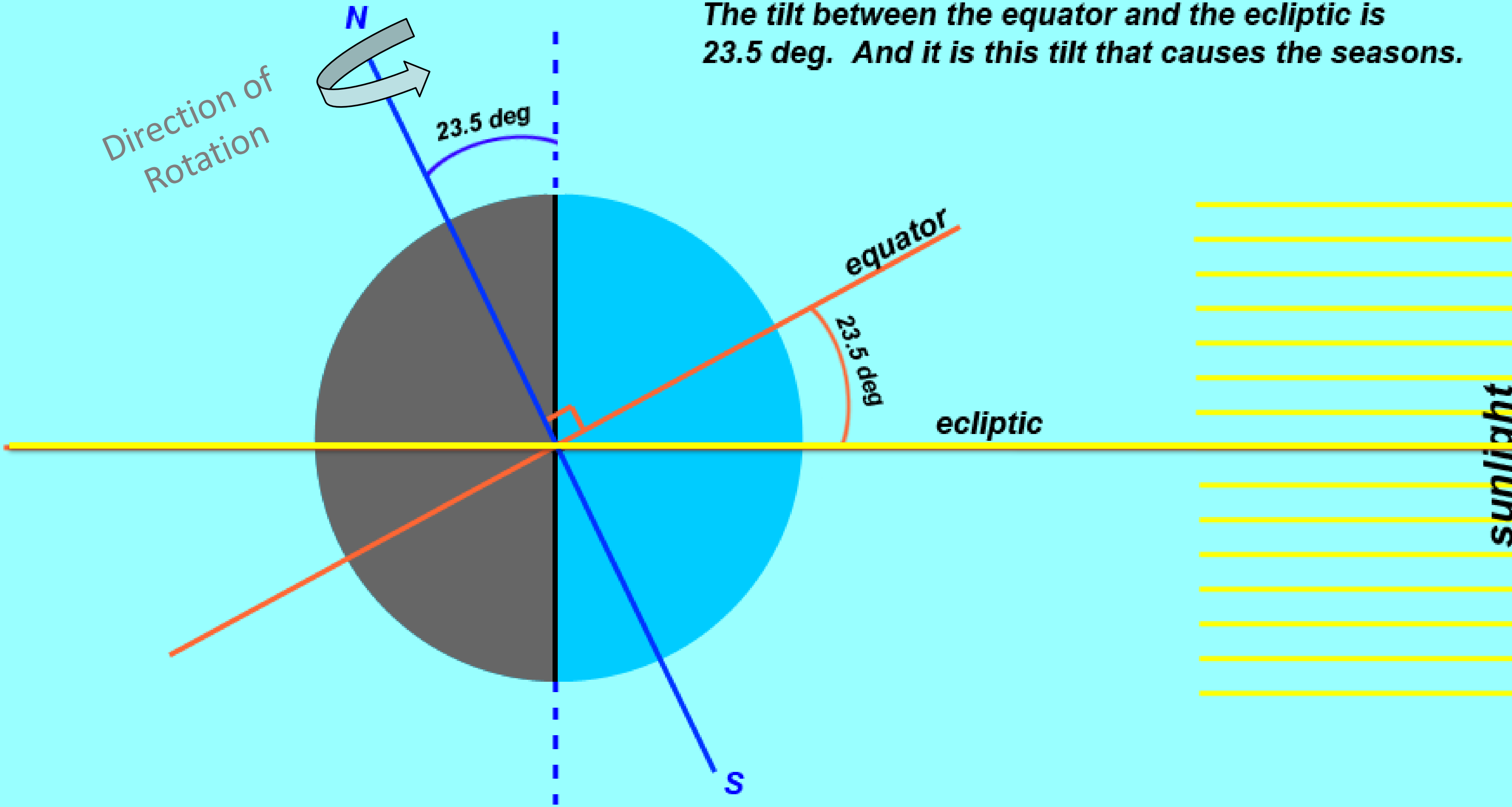
if the rotation axis were perpendicular to the ecliptic plane, the celestial equator would lie along the ecliptic....

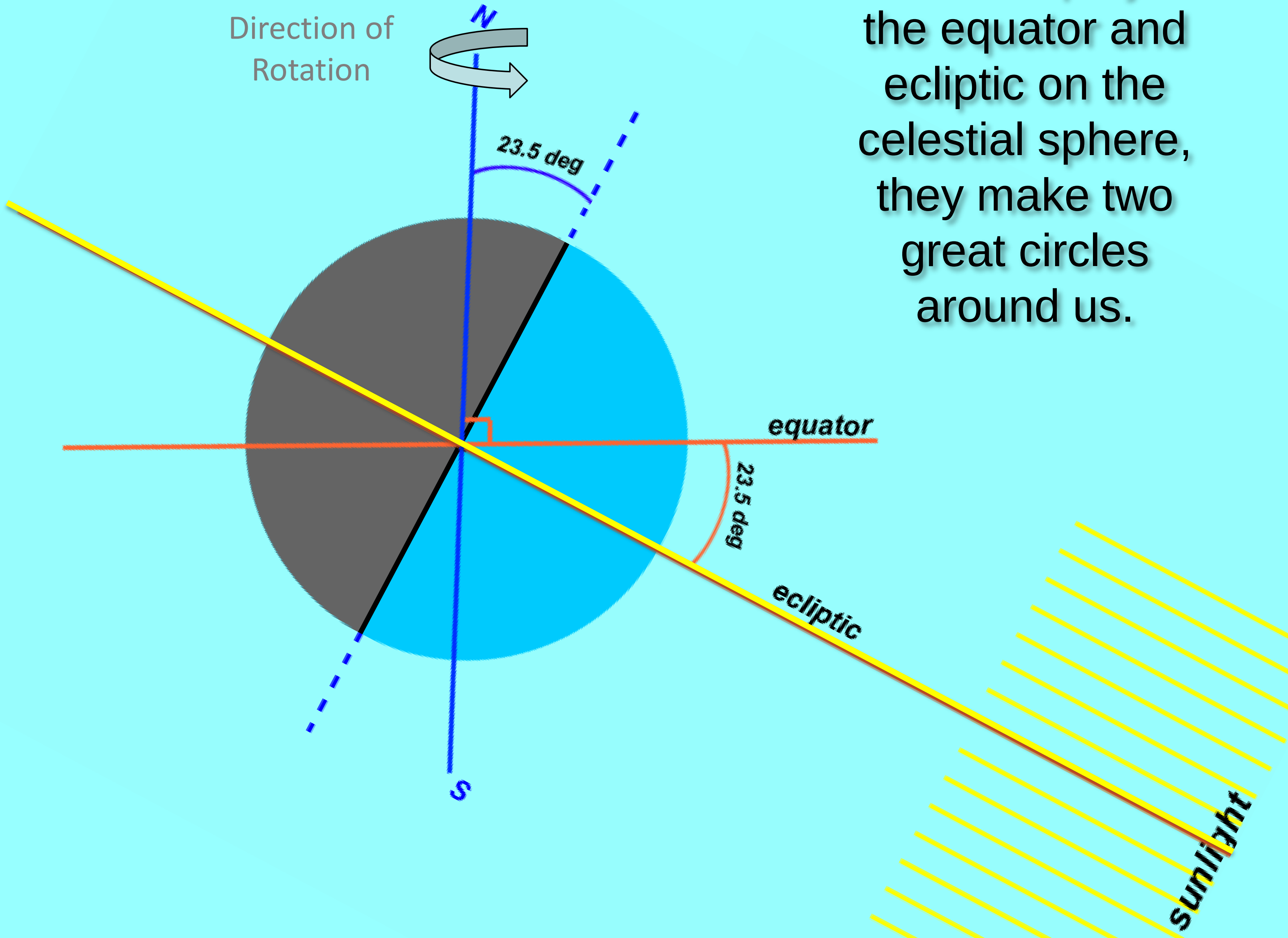


... but Earth was hit by something a long time ago which tilted its rotation axis, and therefore the celestial equator does NOT lie along the eliptic.

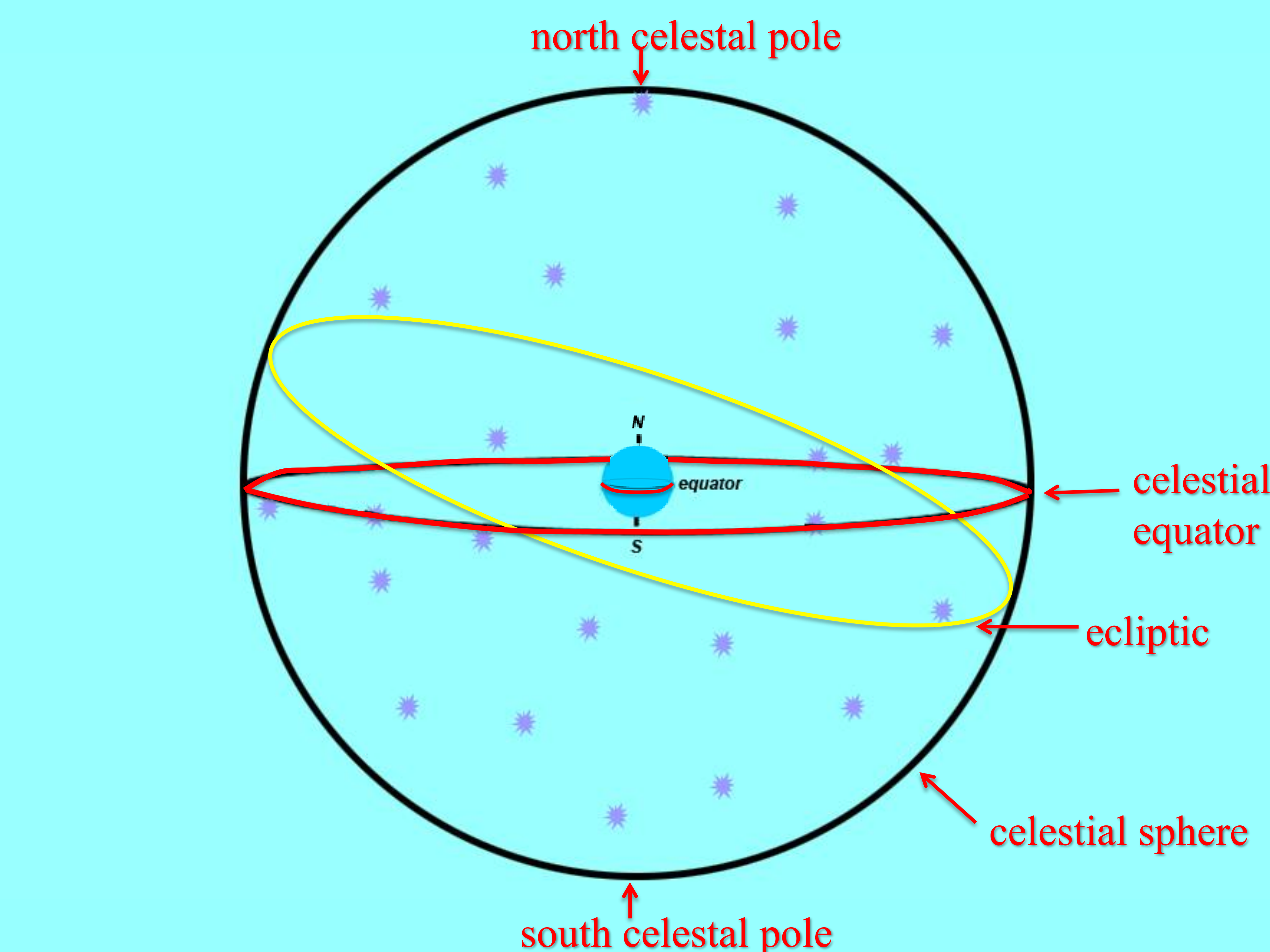


The tilt between the equator and the ecliptic is 23.5 deg. And it is this tilt that causes the seasons.

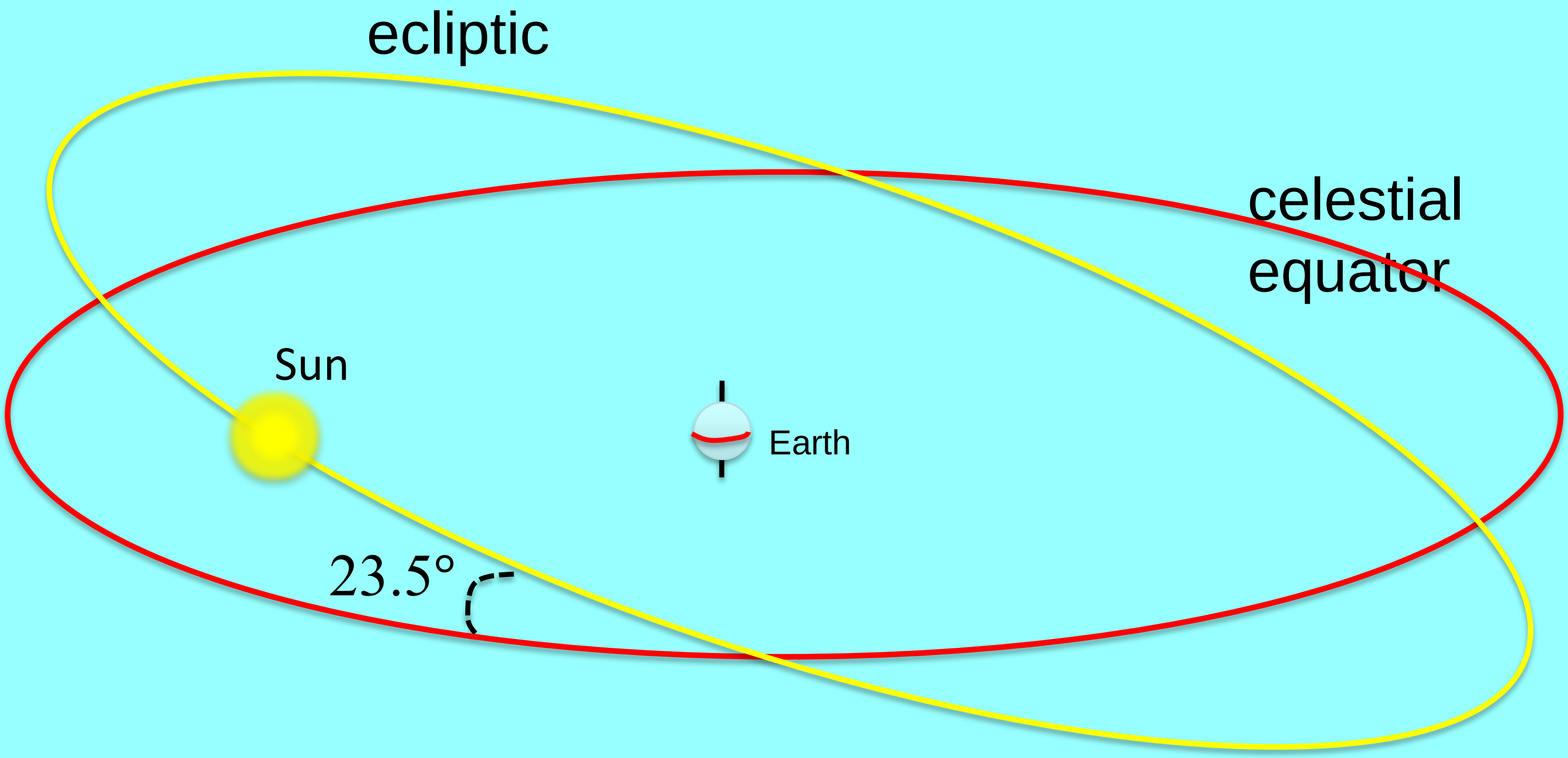




When we project the equator and ecliptic on the celestial sphere, they make two great circles around us.

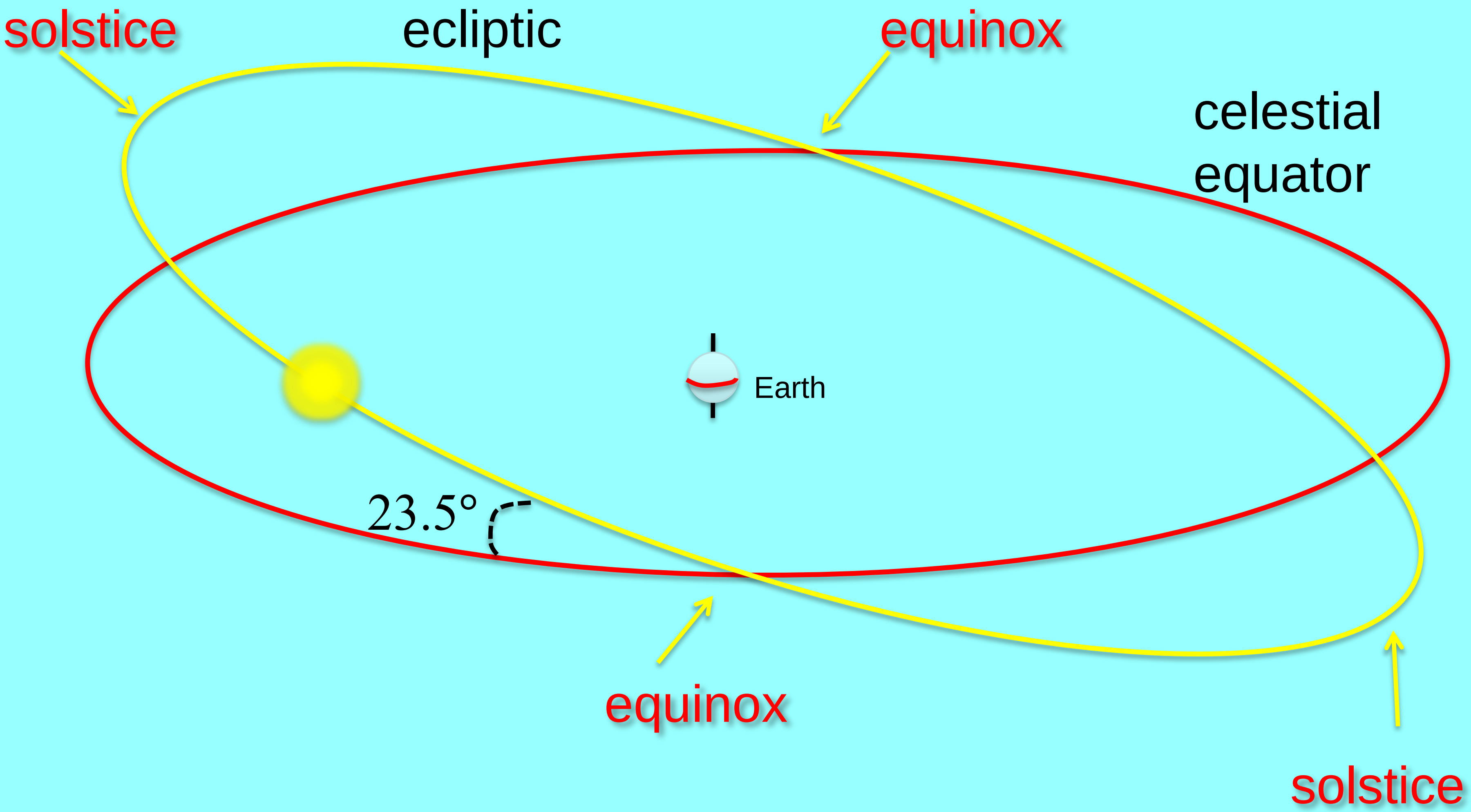

north celestal pole
N
equator
S
celestial
equator
ecliptic
celestial sphere
south celestal pole

To an observer on earth, the sun and planets appear to revolve around the earth along the ecliptic

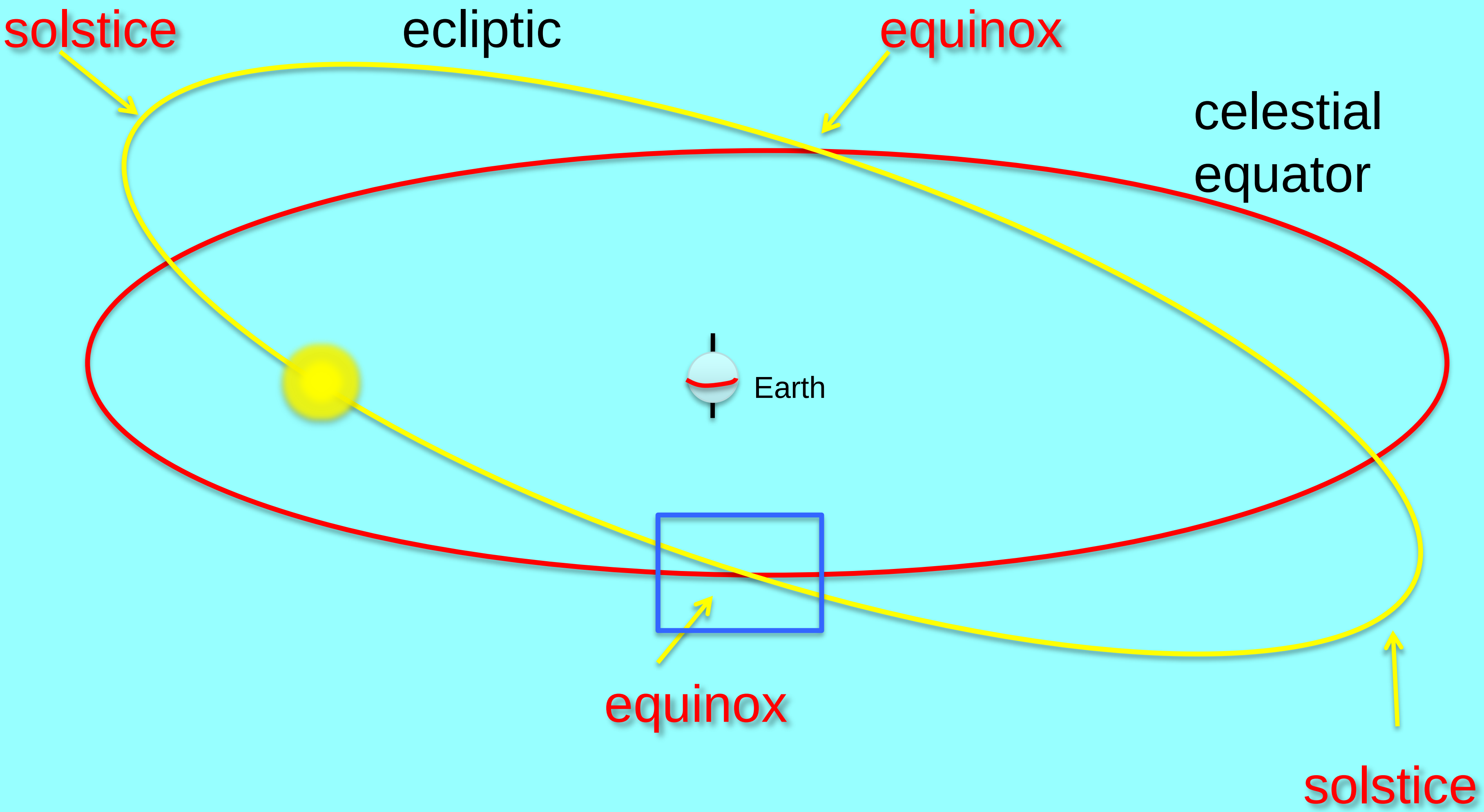


From our view on the ground, the Ecliptic is the apparent path the Sun and planets take over the course of the year and it intersects in 2 places with the Celestial Equator

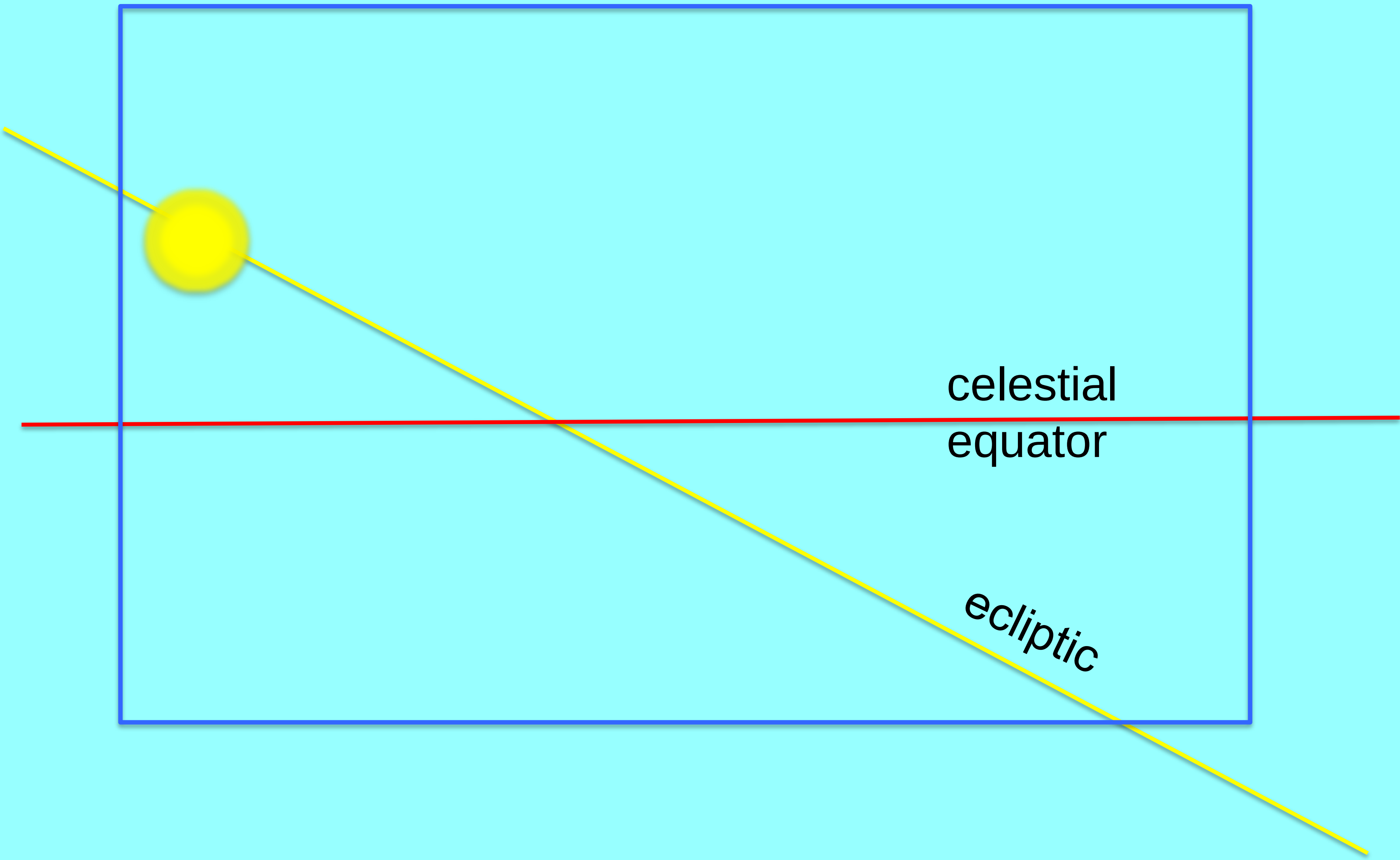
When the Sun is on one of the cross-overs, we call it the **EQUINOX**
When the Sun is as far as possible from the celestial equator, we call it the **SOLSTICE**



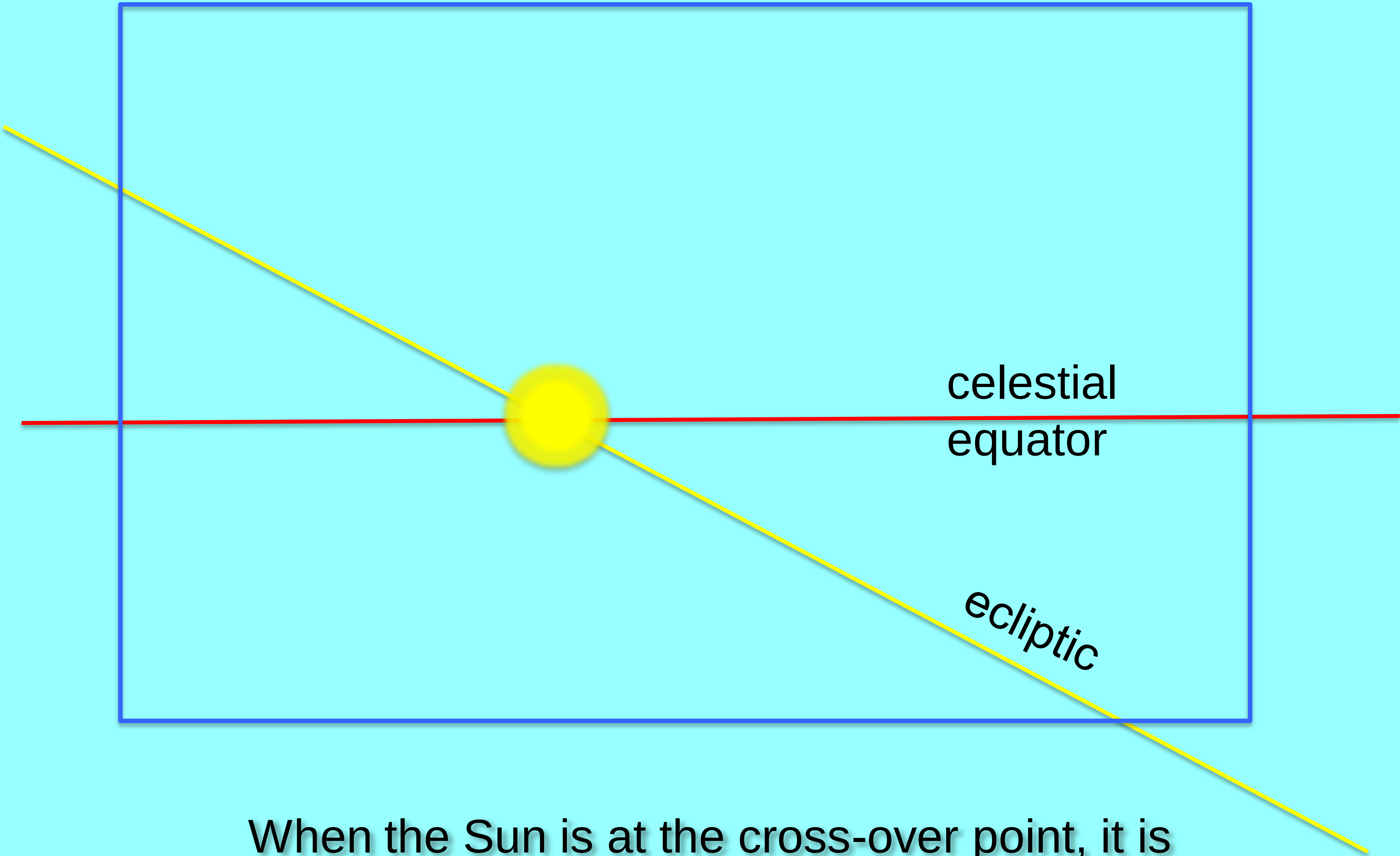
Consider the marked equinox:



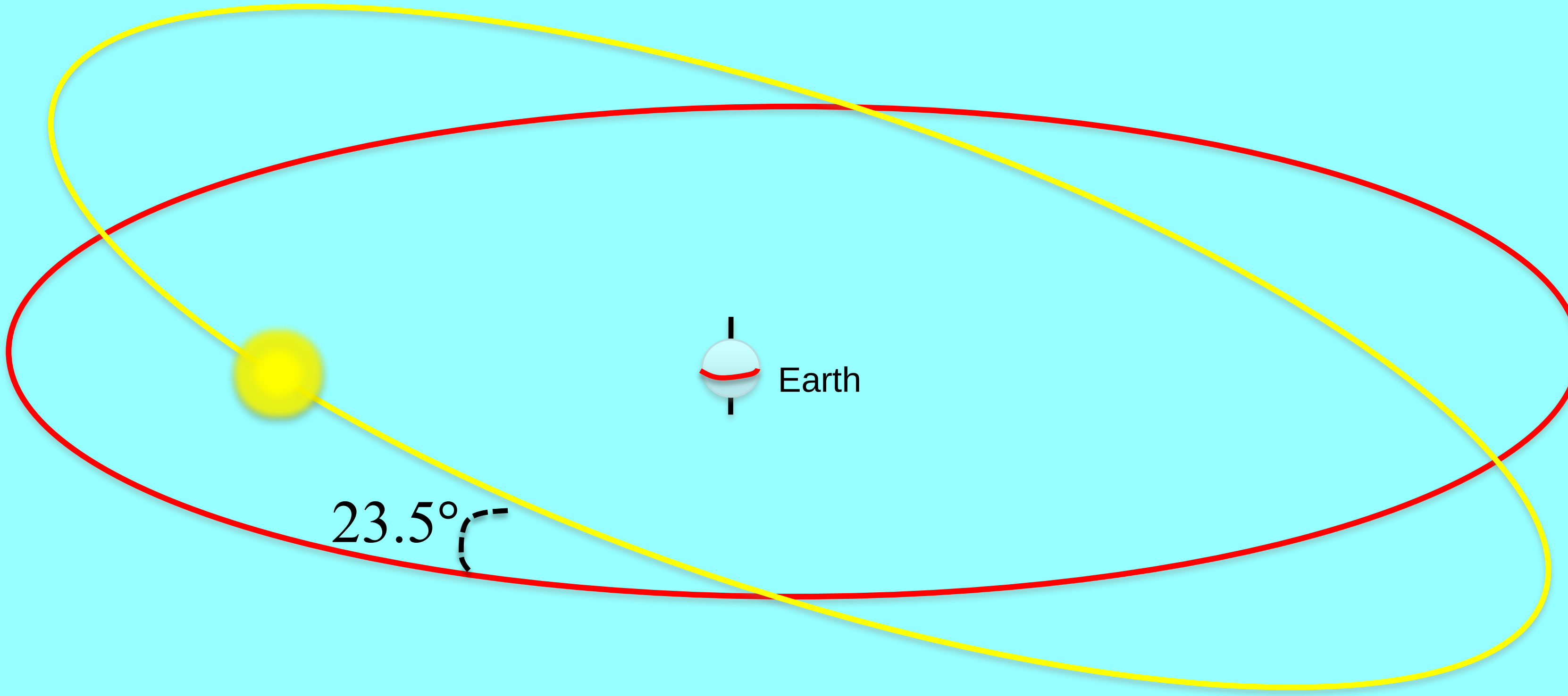
The view from Earth



The view from Earth

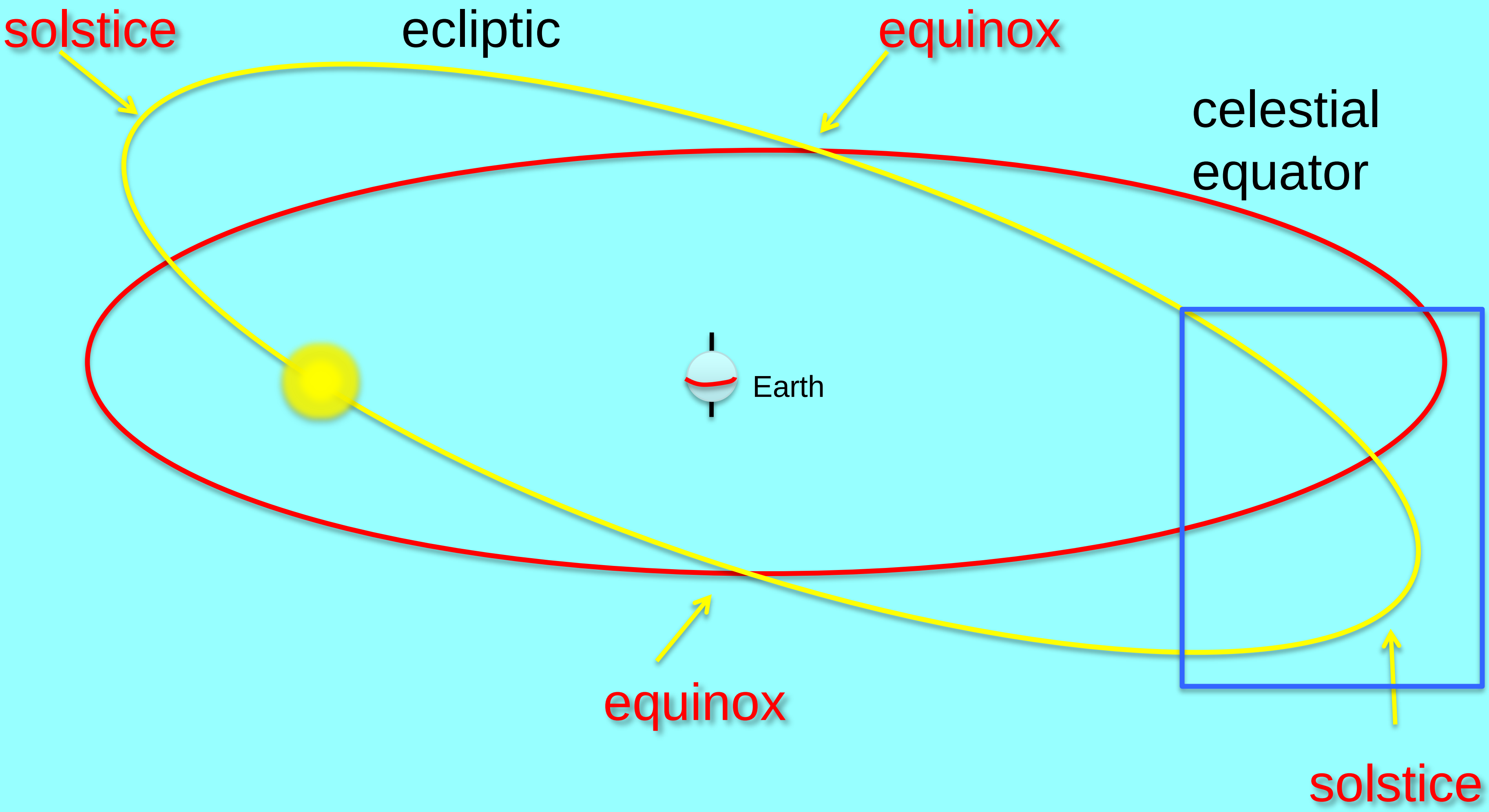


When the Sun is at the cross-over point, it is the EQUINOX

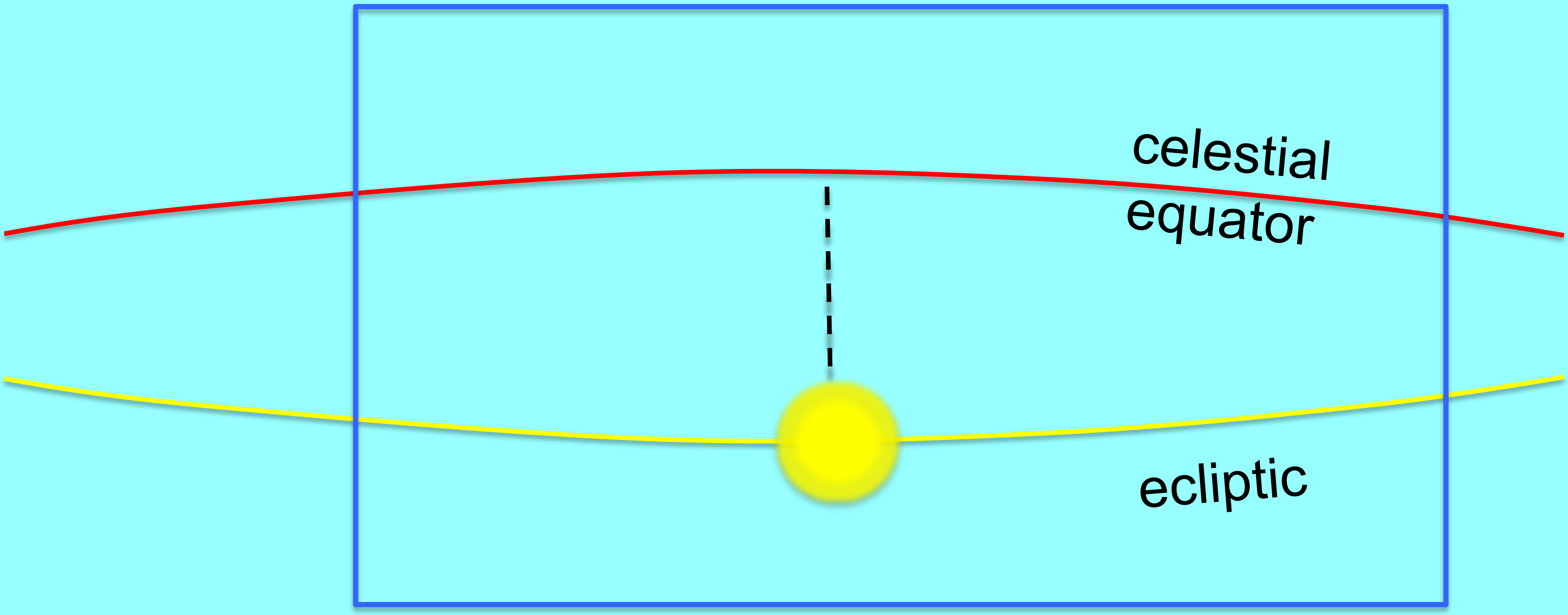


Earth's precession causes the exact location of the equinoxes to move a little each year

Consider the marked solstice:

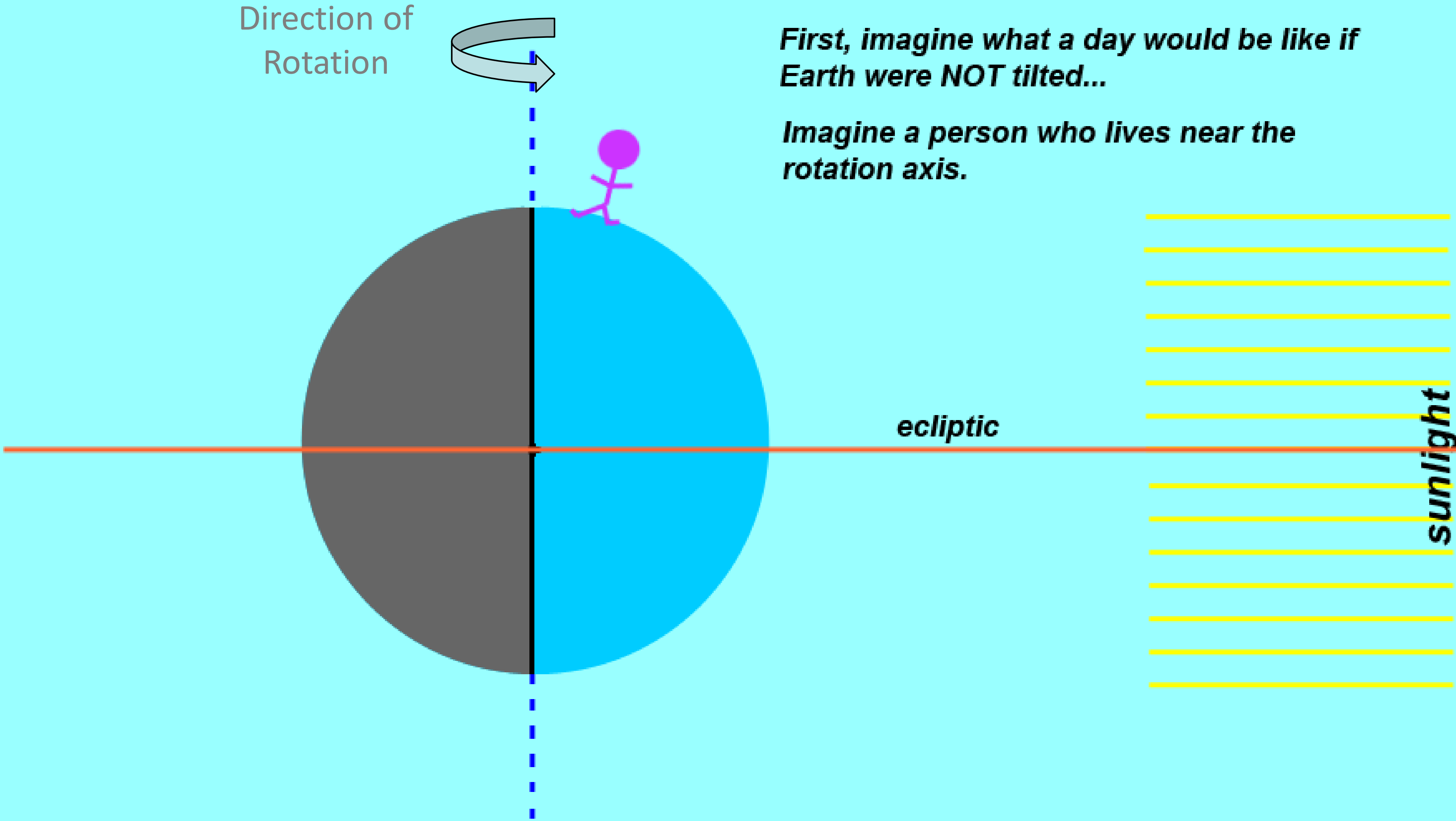


The view from Earth



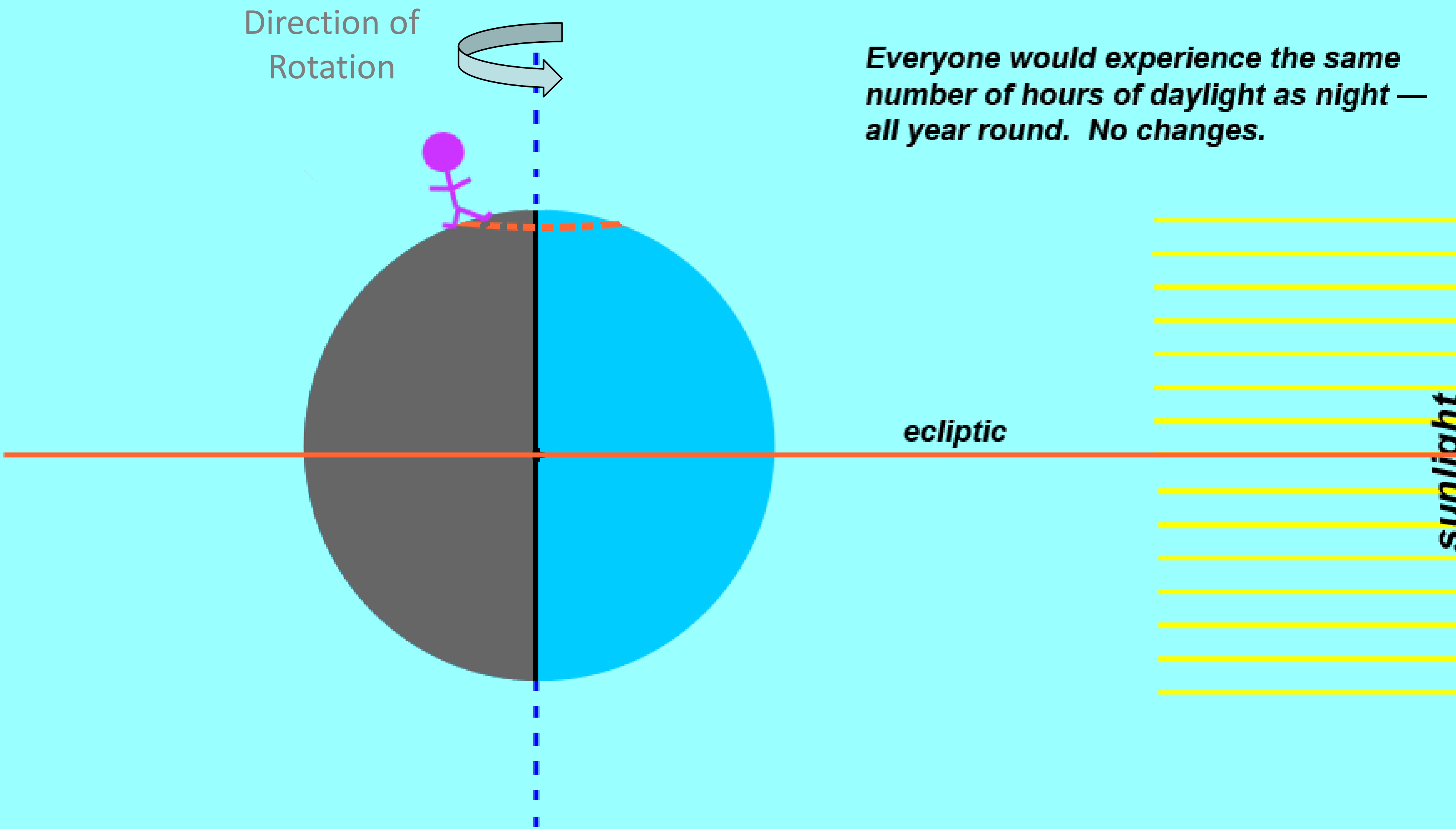
From our view on Earth when the Sun is farthest from the celestial equator, it is the SOLSTICE

The Earth's Tilt and the Seasons:



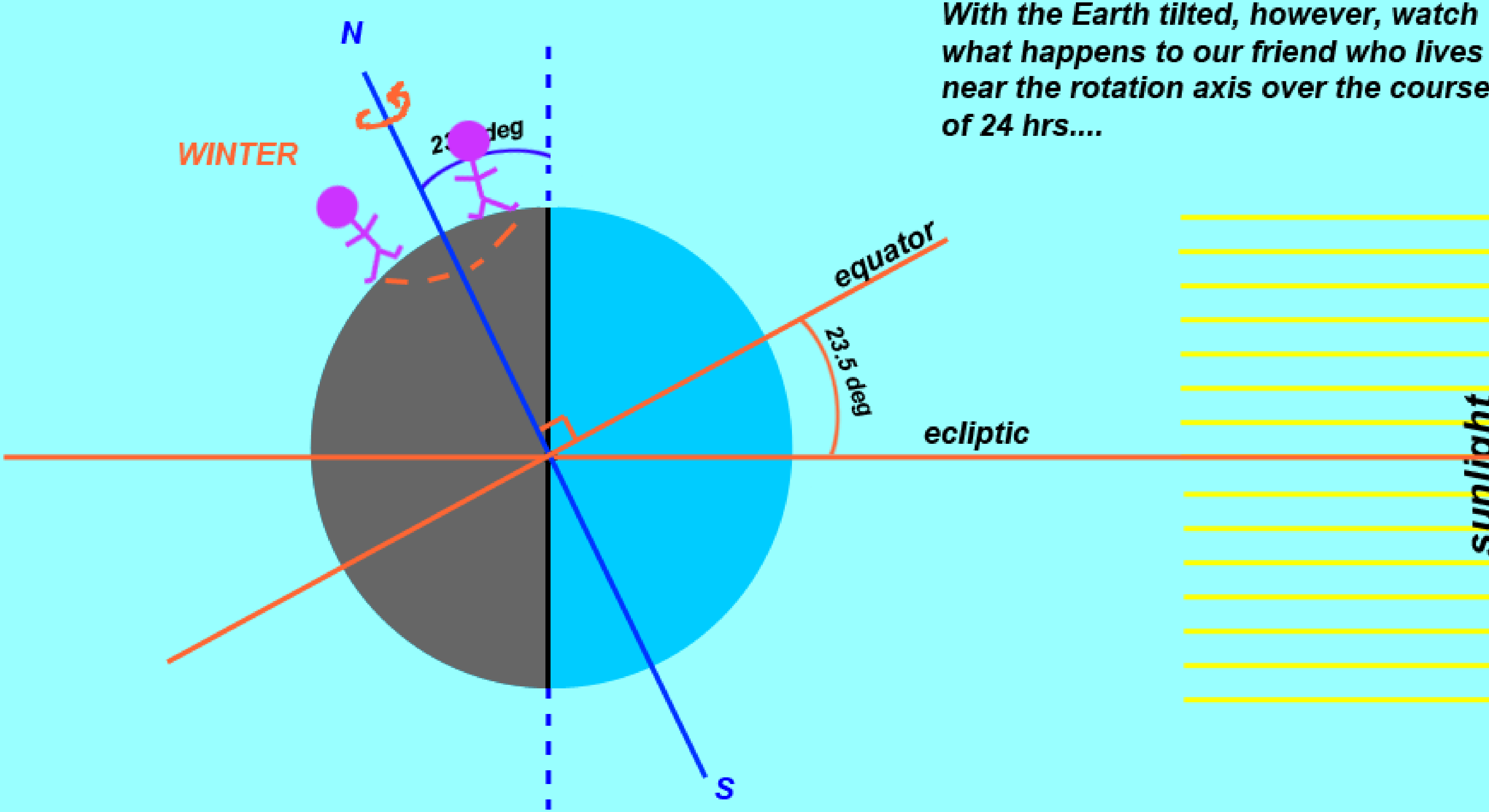
First, imagine what a day would be like if Earth were NOT tilted...

Imagine a person who lives near the rotation axis.

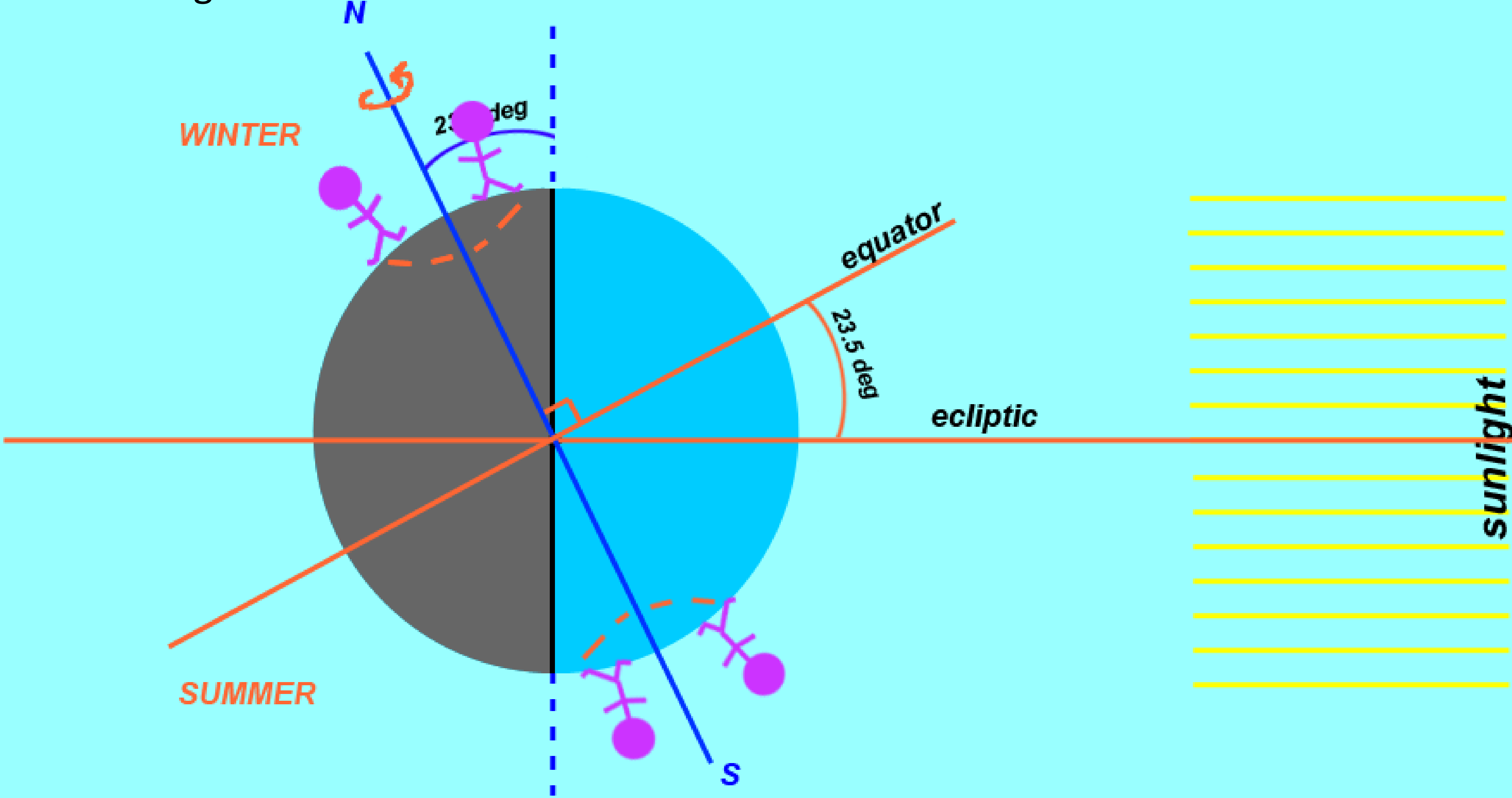


Everyone would experience the same number of hours of daylight as night — all year round. No changes.

With the Earth tilted, however, watch what happens to our friend who lives near the rotation axis over the course of 24 hrs....

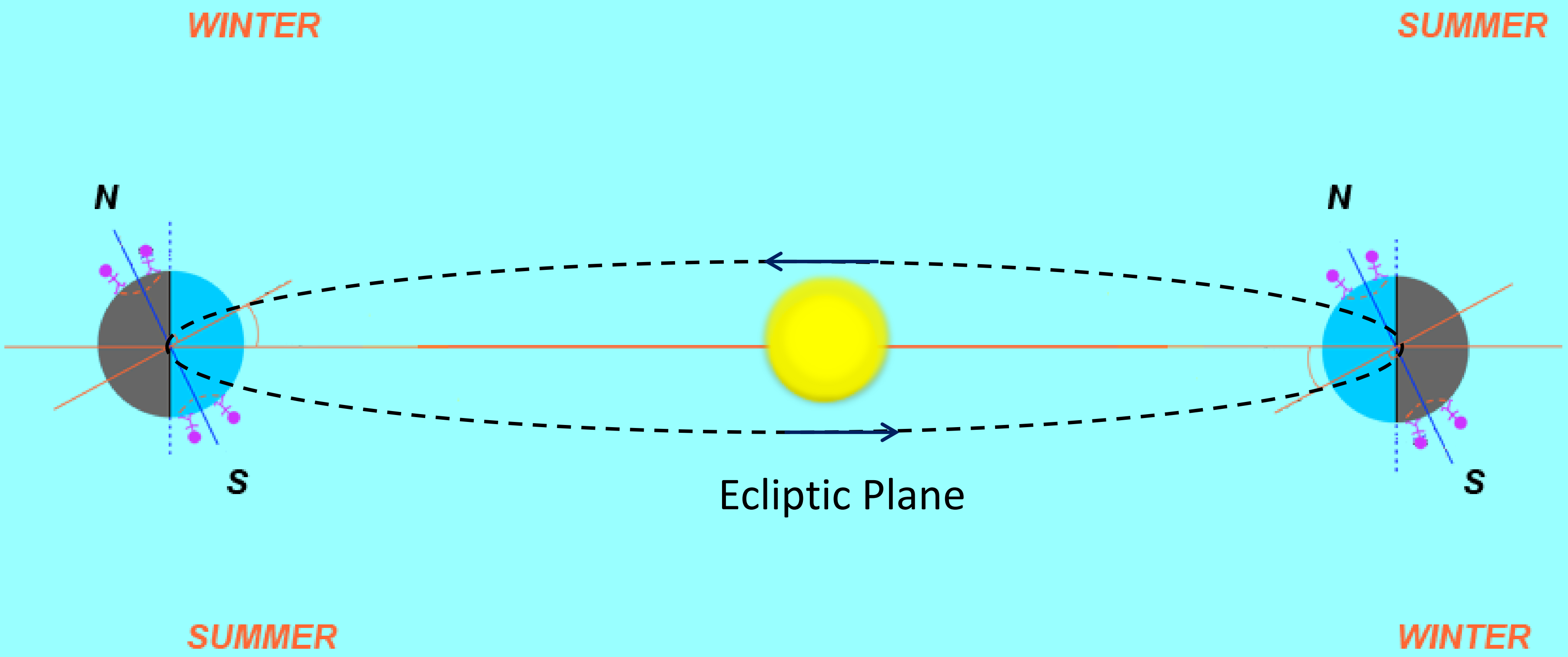


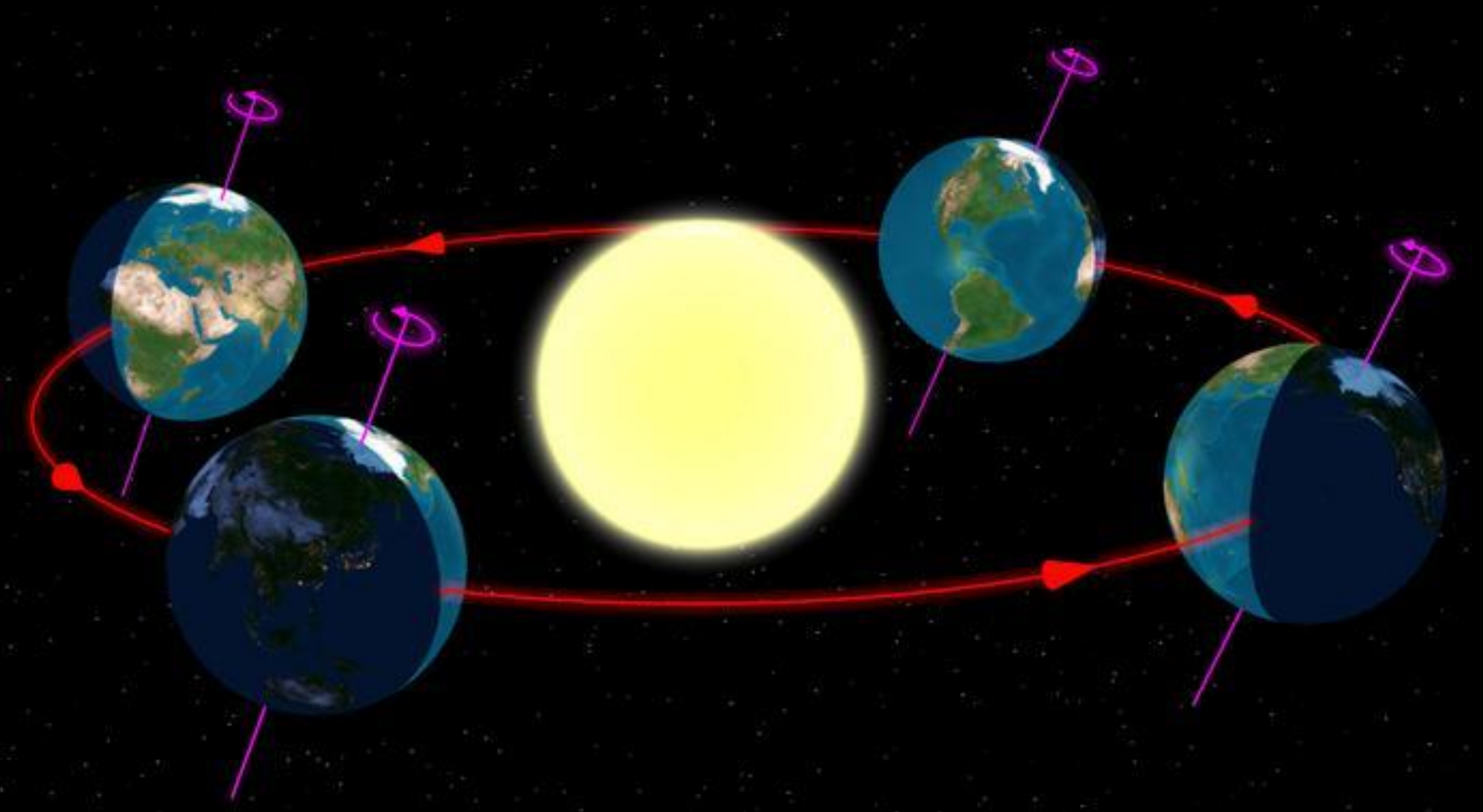
24-hr night



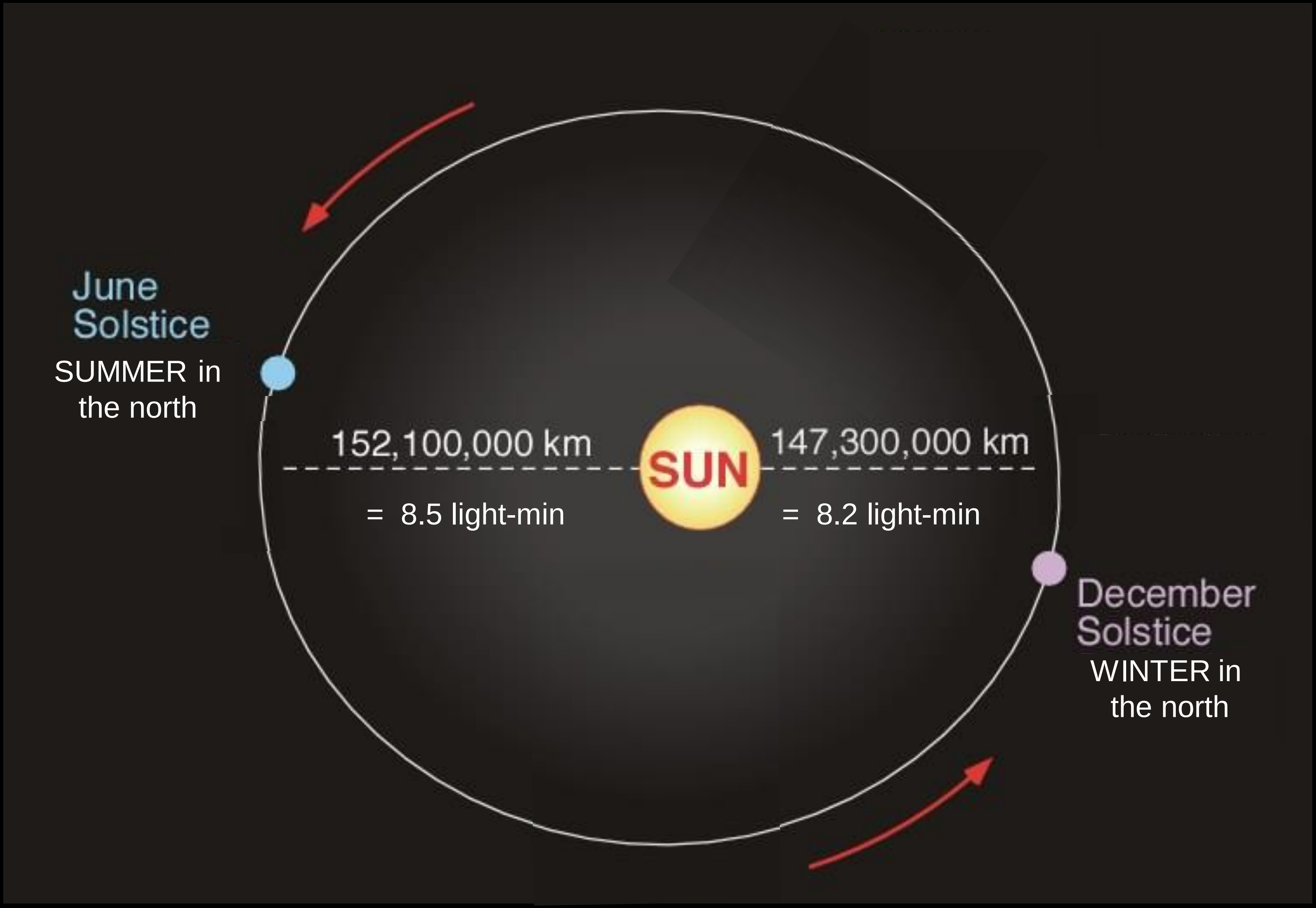
24-hr day

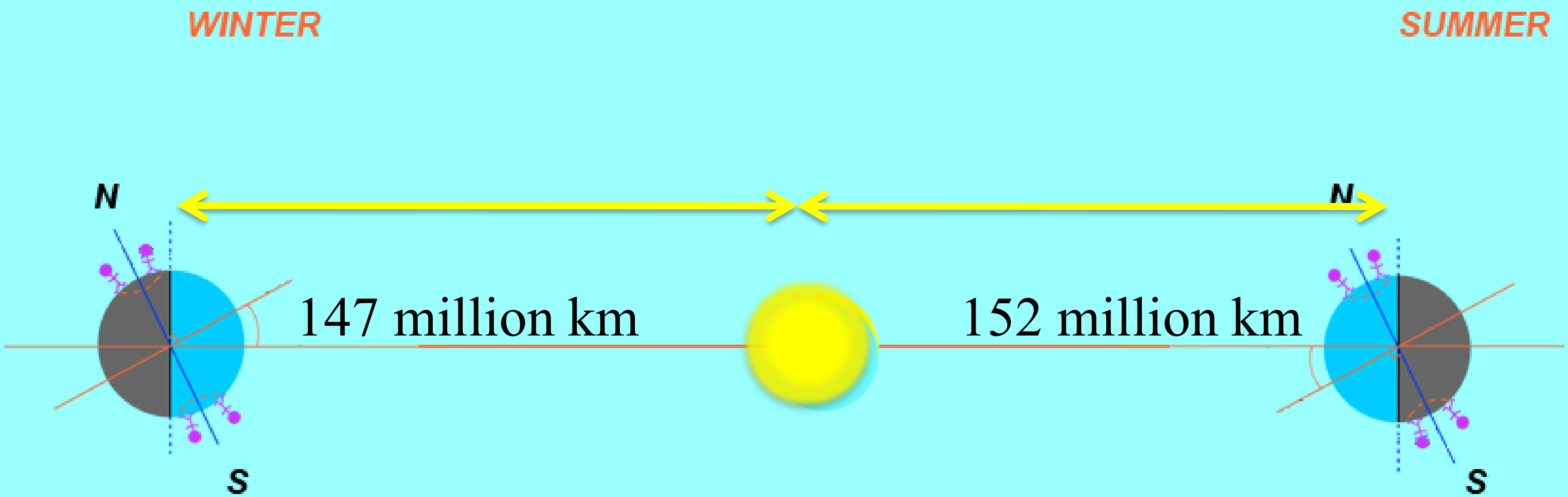
6 months later, the seasons are exchanged.
Note that the tilt of the Earth is the SAME





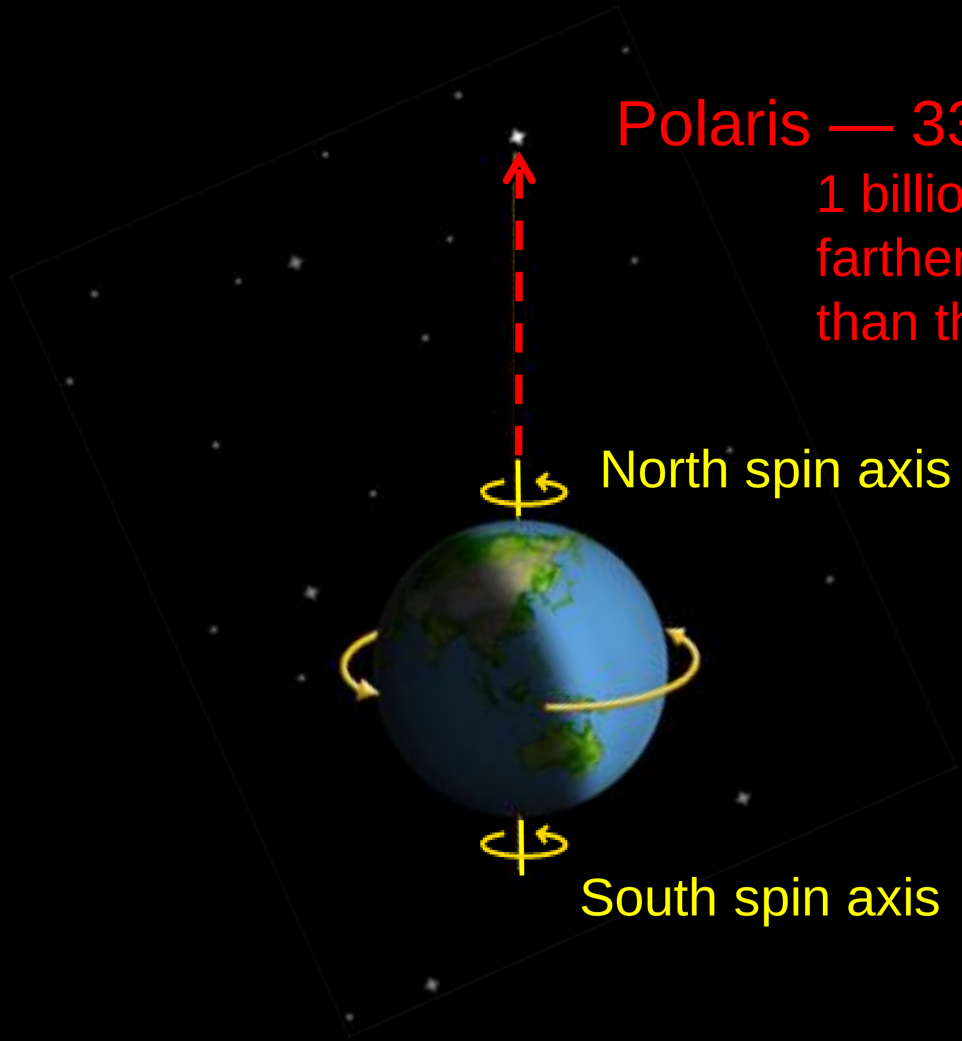
Notice that the tilt does not change

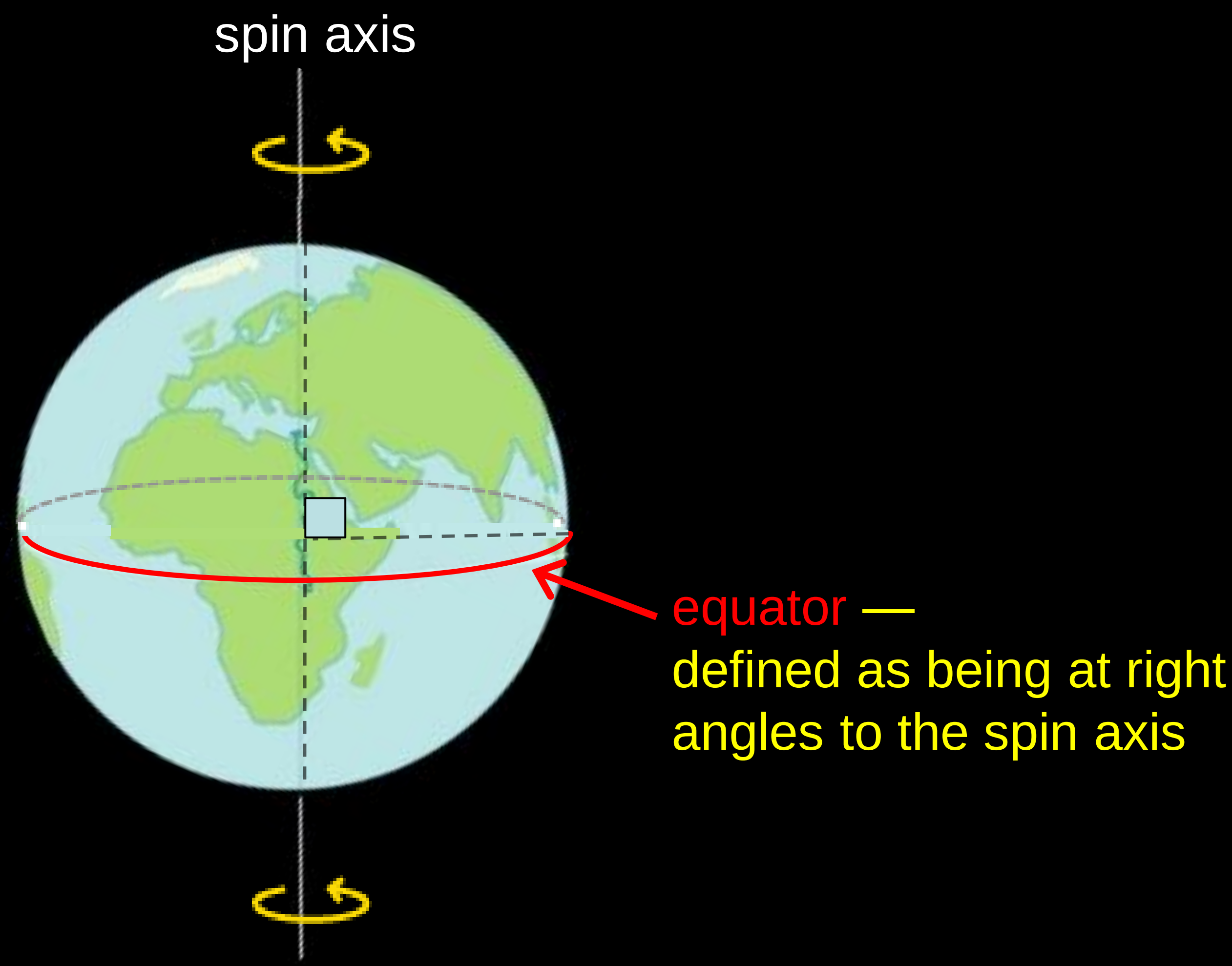

June
Solstice
SUMMER in
the north
152,100,000 km
= 8.5 light-min
SUN
147,300,000 km
= 8.2 light-min
December
Solstice
WINTER in
the north



Note that in the Northern Hemisphere, the Sun is CLOSER to Earth in WINTER, and that the Sun is FARTHER from Earth in SUMMER

THE SEASONS ARE CAUSED BY EARTH'S TILT — **NOT** ITS DISTANCE FROM THE SUN


Polaris — 330 l-yr —
1 billion times
farther from Earth
than the Sun
North spin axis
South spin axis


spin axis
equator —
defined as being at right angles to the spin axis